ISLAND INSTITUTE

Greenhouse Gas Emissions

LOBSTER AND CRAB

A Study of LUKE'S LOBSTER

COMMISSIONED BY: Island Institute
PREPARED BY: Council Fire
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FOREWORD FROM ISLAND INSTITUTE

INTRODUCTION

Purpose

Maine's seafood sector is a cornerstone of the state's economy and identity—and increasingly, a vital player in climate solutions. Between 2022 and 2024, Island Institute commissioned greenhouse gas (GHG) assessments—analyses that measure the amount and sources of GHG associated with specific activities—to better understand the emissions footprint of Maine's lobster, mussel, kelp, and oyster supply chains.

Island Institute's GHG assessment reports provide a foundational benchmark for understanding how seafood producers can cut emissions, lower operating costs, and adapt to changing climate and market conditions. Using illustrative case studies and quantified results, these analyses identify practical solutions and highlight clear opportunities to implement state-level policies and programs that encourage energy-efficient, climate-smart practices. These efforts also strengthen the sector's resilience to other climate change impacts, helping to position Maine as a leader in sustainable seafood production.

This report supports many of the recommendations in the 2024 update to *Maine Won't Wait: A Four-Year Climate Action Plan* and the *2025 Plan for Infrastructure Resilience*, produced by the Infrastructure Rebuilding and Resilience Commission. Island Institute highlights specific opportunities closely aligned with these plans and offers meaningful benefits to the sector.

Methodology

To understand the GHG emissions associated with Maine's seafood sectors, third-party analyses of businesses were conducted using standardized lifecycle accounting protocols to quantify carbon emissions across every major stage of production—from bait sourcing and vessel fuel use to processing, storage, and distribution.

While the businesses studied—Luke's Lobster, Bangs Island Mussels, Atlantic Sea Farms, Mook Sea Farm, Deer Isle Oyster Company, Bombazine Oyster Company (formerly Ferda Farms), and Pemaquid Oyster Company—are leaders in their respective fields, the goal was not to produce industry-wide averages. Instead, these businesses served as illustrative case studies, offering a real-world snapshot of emissions sources and reduction opportunities.

Data was collected directly from the companies and supplemented with interviews, site visits, and operational records. Upstream and downstream impacts, such as aquaculture seed production, fuel sourcing, and product distribution, were also modeled where possible. All GHG analyses in these reports follow the steps and guidelines as defined by the International Organization for Standardization (ISO) standards. Results are presented in accordance with ISO standards and categorized based on the GHG Protocol Corporate Accounting and Reporting Standards. Each case study reflects the best available data from a specific point in time and is intended to inform—not define—sector-wide practices.[i] Importantly, all of the findings, connections, and recommendations in these reports are based on analyses of seafood businesses and are meant to be illustrative examples. They are not assumed to be representative of their entire respective seafood industry.

i Three separate consultants were used across the reports. While all followed standard GHG protocols, some differences in approach were inevitable.

WHAT'S AT STAKE

Natural resource-dependent businesses like fishing, aquaculture, and other marine-based industries are particularly vulnerable to climate and environmental changes that could significantly impact Maine's economy. Maine's seafood sector alone contributed over $3.2 billion dollars in total economic input to the Maine economy in 2019 and employed more than 34,000 people, but this sector and the jobs it supports is currently facing many harmful impacts from ocean climate change.[ii]

The seafood sector is at the onset of a once-in-a-century energy transition as it looks for ways to decarbonize through electrification, low-carbon fuels, optimization tools, and efficiency technologies.[iii] If Maine is to meet its climate goals, and we are to avoid the worst impacts of change in all sectors, including the marine sector, we must drastically reduce emissions.[iv] By drastically reducing emissions, we will be less vulnerable to environmental and economic risks.

EXECUTIVE SUMMARY

Maine's coastal communities are facing rising seas, stronger storms, aging infrastructure, and increasing energy costs. These challenges threaten not only individual businesses, but the viability of Maine's iconic working waterfronts and the greater marine economy.

At the heart of this effort is a systems-level challenge: How can we sustain and grow Maine's marine economy while modernizing infrastructure, reducing emissions, and increasing resilience—especially when time, funding, and capacity are in short supply?

Drawing on a long history of working directly with community leaders and business owners, Island Institute commissioned a series of GHG analyses to measure the carbon footprint of key seafood supply chains. The goal of these studies is two-fold: first, to assess options that enable seafood businesses to reduce emissions, lower operating costs, and adapt to changing climate and market conditions; and second, to identify practical solutions—supported by illustrative case studies and quantified results—and highlight clear opportunities to implement state-level policies and programs that promote energy-efficient, climate-smart practices.

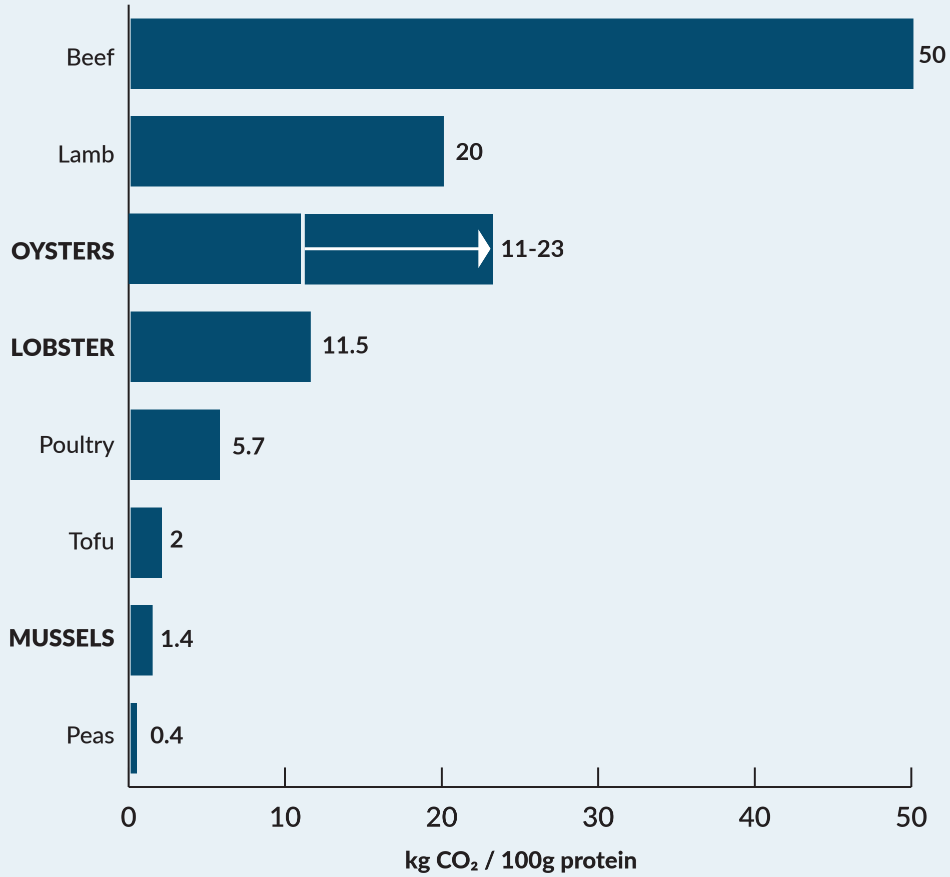
The findings are clear: Maine seafood is already among the lowest-carbon protein sources available (Figure A). At the same time, meaningful opportunities exist to reduce emissions for businesses operating on the front lines of climate change.

Clean energy and decarbonization efforts bring co-benefits to the seafood sector. Through GHG emissions reductions, marine businesses can reduce their contribution to global climate change, a key driver in business uncertainty. Reducing emissions also stabilizes or lowers operating costs, allowing businesses to reinvest in resilient business operations.

Strategic investments—especially in the electrification of work boats and associated shoreside charging and clean energy infrastructure—can significantly cut emissions, lower long-term operating costs for businesses, and strengthen Maine's leadership in sustainable food production. For example, replacing a single 100-horsepower, four-stroke internal combustion outboard engine with an equivalent power electric outboard motor would reduce operations emissions by 11–16 metric tons per year.[v]

ii SEA Maine Roadmap
iii https://www.energy.gov/eere/maritime-decarbonization
iv *Maine Won't Wait Climate Action Plan*
v Estimation based on calculations of real-world electrification projects implemented by Island Institute with partner businesses.

Figure A. Results from GHG assessments of Maine seafood businesses compared to common land-based protein sources.[vi]



Each report underscores the opportunity for targeted investments in this sector to help businesses take advantage of existing State and Federal programs that can reduce emissions in the building envelope and in the transportation sector. These reports also highlight the importance of continued data collection and piloting ways to reduce on-the-water emissions. Cutting emissions through efficiency measures that reduce the need for energy, in any form, results in lower operational costs. For example, phase change materials can help reduce demand from the electrical grid during peak demand hours, reducing costs for the business, and helping to reduce emissions and stress on the grid. In Maine, the mix of electricity on the grid is relatively clean, making the shift from fossil fuels to electricity a cost-effective, climate friendly strategy.

This report offers a path forward. With deeper collaboration, targeted investment, and shared innovation, we can turn these findings into real-world projects that secure Maine's working waterfronts and shape a resilient, sustainable marine economy—one that can serve as a national model.

vi These findings reflect only the results from Island Institute's commissioned studies of individual seafood businesses. They have not undergone third-party verification and should not be used for marketing purposes.

Shared Findings

These in-depth analyses, covering seven Maine seafood businesses, indicate highest emissions in the following three areas:

- Fossil fuel use on fishing and aquaculture vessels.
- On-shore energy consumption for the built environment, including heating, drying, refrigeration, freezing, and hatchery operations.
- Land-based transportation and distribution impacts emissions directly or indirectly for all aspects of business operations. Emissions from distribution activities are highly variable depending on distance covered and distribution method.

Recommendations for Business

- Transition on-land medium-and heavy-duty vehicles, as well as on-the-water vessels, to non-fossil fuel-based energy sources (i.e., electric and hybrid vehicles and vessels).
- Increase charging infrastructure located at or near the water's edge to accommodate vehicle and vessel electrification.
- Improve operational efficiency through process optimization and smart technologies to reduce run time in daily farming operations.
- Improve operational efficiencies on the shore-side processing and handling facilities to lower energy use, GHG emissions, and operational costs.
- Improve crop yields and minimize waste by upgrading farming gear and on-the-water processing equipment.

RECOMMENDATIONS FOR POLICY AND STATE PROGRAMS

Proven solutions exist to tackle some of these high emission areas, while also delivering long-term financial benefits to Maine's seafood businesses. As with many energy efficiency-related improvements, these solutions may require upfront capital costs to see a longer-term shift in operating costs. While existing statewide incentive programs for energy efficiency upgrades and clean energy transition can support this work, there is an opportunity to expand these programs to meet and improve the efficiency of building and shoreside transportation needs for the seafood sector. Tailoring communication and outreach about these opportunities to individuals who work in the working waterfront and on the water could accelerate energy efficient and clean energy adoption and reduce emissions in the sector.

At the same time, emerging technologies—particularly related to transitioning marine work boats from fossil fuels to electric propulsion—hold significant promise and merit further exploration. Electric outboards are currently being piloted by members of the aquaculture industry, and this technology continues to show promise for reducing operational cost and carbon emissions. Using the existing statewide incentive programs as models could help incentivize and de-risk the adoption of newer technologies critical to the transition away from fossil fuels.

These recommendations align with statewide priorities outlined in both the updated *2024 Maine Won't Wait: A Four-year Climate Action Plan*, as well as the *2025 Plan for Infrastructure Resilience*. In many cases, these recommendations reinforce or expand goals already established by the State.

The Infrastructure Rebuilding and Resilience Commission 2025 report outlines recommendations to protect infrastructure, including working waterfronts, from elevated storm impacts related to climate change. The *Maine Won't Wait* plan underscores the importance of helping businesses with clean energy solutions. As noted in the plan: "[making businesses more climate friendly can save on both operating costs and emissions" and we need to "[h] elp Maine businesses and other entities take advantage of electrification, efficiency, electric vehicle, and clean-manufacturing business incentives and recognize exceptional efforts."[vii]

Many seafood businesses, however, lack the time, resources, and technical expertise to implement these solutions on their own. Successfully implementing these recommendations will require substantial capacity-building and technical support from organizations within the sector. With the right assistance at a state-wide scale, Maine's seafood businesses can modernize their infrastructure, lower emissions, enhance resilience, and ultimately strengthen and grow the state's marine economy.

Specific recommendations include:

- Increase awareness and uptake of existing programs, particularly Efficiency Maine Trust's Custom Program, to support efficiency upgrades in the built environment by the seafood sector.[viii]
- Assess whether the seafood sector represents a good use case for medium- and heavy-duty vehicle electrification and prioritize this sector for implementation support because of the co-benefits to adaptation for these businesses.[ix]
- Support the collection of data on the performance and long-term cost and emissions reductions of electric and hybrid work vessels through demonstration projects. Use data to expand existing electric vehicle incentives to cover marine vessels and shoreside infrastructure.[x]
- Maintain and increase access to capital—including low-interest loans with flexible terms and other incentives such as tax credits or grants—to help defray the costs of energy efficiency and beneficial electrification upgrades.[xi]
- Support and incentivize businesses to take advantage of behind-the-meter clean energy generation and storage—such as on-site solar panels that power a business directly without relying on the grid.[xii]
- Support research to better understand the use of kelp aquaculture might help capture and store carbon.[xiii]

"Some sectors of Maine's marine economy have electrification and emission reduction opportunities, while others require more innovation and clean-fuel options... Maine and key stakeholders should continue to support innovation and efforts to help commercial marine and small harbor craft adopt electrified propulsion and other low- and zero-emission vessel technologies."
— Maine Won't Wait, A Four-Year Climate Action Plan for Maine, 2024 Update

vii *Maine Won't Wait 2.0* (2024) Strategy D2, pages 93 and 98 (2024)
viii *Maine Won't Wait 2.0* (2024) Strategy B1 - Boost efficiency in commercial and institutional buildings through high-efficiency electric heating and water heating systems, building control technologies, and improvements to building envelopes.
ix *Maine Won't Wait 2.0* (2024) Strategy A2 - By 2028, pilot projects for zero-emission trucks, municipal and school buses, ferries, and boats to demonstrate and evaluate performance, reliability, and cost savings. Develop an incentive program for zero-emission medium- and heavy-duty vehicles.
x *Maine Won't Wait 2.0* (2024) Strategy A2 - By 2028, pilot projects for zero-emission trucks, municipal and school buses, ferries, and boats to demonstrate and evaluate performance, reliability, and cost savings. Develop an incentive program for zero-emission medium- and heavy-duty vehicles.
xi *Maine Won't Wait 2.0* (2024) Strategy C-1 Decrease energy burdens while transitioning to clean energy - Expand financing and ownership models for Maine people and businesses to access clean energy and energy efficiency opportunities.
xii *Maine Won't Wait 2.0* (2024) Strategy C-1 Decrease energy burdens while transitioning to clean energy - Expand financing and ownership models for Maine people and businesses to access clean energy and energy efficiency opportunities.
xiii *Maine Won't Wait 2.0* (2024) Increase the total acreage of conserved natural and working lands in the state to 30 percent by 2030.

A NOTE ON GRID INFRASTRUCTURE

A significant barrier to implementing energy efficiency, clean energy, and future electrification technologies is the current grid condition, including aging infrastructure and energy capacity capabilities. Recommendations in both *Maine Won't Wait* plan and the *Plan for Infrastructure Resilience* highlight the importance of strengthening the resilience of the State's electrical grid. This is especially critical for seafood businesses who operate on the edges of the grid, including working waterfronts and islands. Investing in island and coastal grid infrastructure will contribute to improving reliability and capacity, enabling more businesses to tap into clean, grid-powered energy, and support future community and economic development and resiliency. Expanding power capacity in these remote areas will enable the electrification of equipment and charging infrastructure that requires 3-phase power, a type of electrical power commonly used for large commercial or industrial operations. Only approximately 25% of Maine's coast currently has access to 3-phase power.[xiv] Upgrading the infrastructure to accommodate these high-power uses is critical to expand electrification and decarbonization strategies in the seafood sector.

xiv This data comes from a forthcoming shoreside charging infrastructure report comissioned by Island Institute.

ACKNOWLEDGEMENTS

This work would not have been possible without the following funders, seafood businesses, and consultants, whose collaboration was critical for this body of work:

Atlantic Sea Farms	Participating Seafood Business
Bangs Island Mussels	Participating Seafood Business
Bombazine Oyster Company (formerly Ferda Farms)	Participating Seafood Business
Council Fire	Consultant, Luke's Lobster Report
Dana Morse	Darling Marine Center
Deer Isle Oyster Company	Participating Seafood Business
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Luke's Lobster	Participating Seafood Business
Merritt T. Carey, Esq	Consultant
Mook Sea Farm	Participating Seafood Business
Nichole Price	Bigelow Laboratory for Ocean Sciences
Pemaquid Oyster Company	Participating Seafood Business
Pure Strategies	Consultant, Bangs Island Mussels and Atlantic Sea Farms Reports
RISE Research Institutes of Sweden	Consultant, Mook Sea Farm, Bombazine Oyster Company (formerly Ferda Farms), Deer Isle Oyster Company, and Pemaquid Oyster Company Reports
Shane Rogers	Clarkson University
Susan Powers	Clarkson University

EXECUTIVE SUMMARY OF LOBSTER STUDY

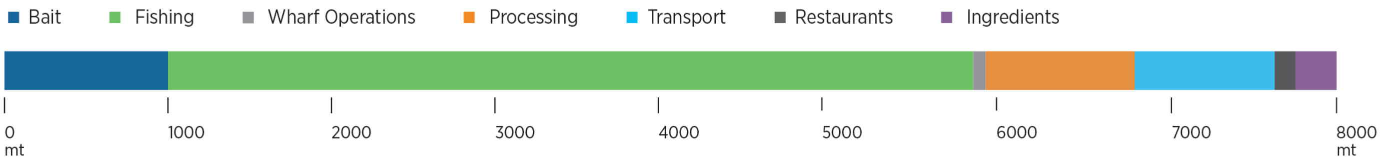
Luke's Lobster is a Maine-based, vertically integrated seafood company working toward a goal of achieving net zero carbon emissions associated with its business operations. To begin making progress on this ambitious goal, Island Institute, on behalf of and in partnership with Luke's, commissioned Council Fire to conduct an assessment of the greenhouse gas (GHG) emissions related to the production and sale of two of its primary seafood products, lobster and crab, with an eye toward identifying and reducing emissions. Because Luke's is involved at every step in the supply chain of its products, from buying and selling bait all the way to serving consumers in restaurants and retail, they have unique access to data on the emission-generating activities at each step. Per standard protocol, GHG emissions have been assessed in three categories: direct emissions (Scope 1), indirect emissions (Scope 2), and indirect emissions occurring upstream and downstream in the company value chain (Scope 3) using 2021 as the reporting year.

GHG emissions were determined by analyzing energy use in lobster and crab harvest, wharf operations and upstream transportation, processing, and in post-processing use in transportation, restaurant locations, and wholesale and retail sales. Results are summarized in the table that follows.[1] It should be noted that Scope 3 emissions are difficult to measure. Accordingly, many companies choose to not measure or pursue explicit reduction targets for these types of emissions. For those that do, it is quite common for the assessment to reveal that Scope 3 is the largest source of emissions. This is the case for Luke's as well. Given the company's commitment to driving sustainability into its own operations and the Maine lobster industry as a whole, Luke's has not shied away from the task of beginning to quantify and reduce as many aspects of Scope 3 emissions as can be reasonably addressed.

Table 1: Summary Emissions Table (All emissions reported in metric tons/reporting year)

Scope	Category or Type of Emissions	Operations Category Within Supply Chain	Total CO2 Equivalent Emissions (mt/yr)
Direct Emissions	Fugitive emissions (leakage, or discharge of gases or vapors)	Processing Restaurants Transport	190.18
Direct Emissions	Fugitive emissions (leakage, or discharge of gases or vapors)	Processing Restaurants Transport	190.18
Direct Emissions	Stationary combustion (emissions from heating, boilers, ovens, other non-movable equipment)	Processing Restaurants	2,660
Direct Emissions	Mobile combustion (emissions from the transportation of materials, products, waste)	Transport	14.81
Indirect Emissions from Purchased Electricity	Emissions from purchased electricity, all named locations	Transport	266.75
Upstream and Downstream Emissions	Category 1a: Purchased goods and services, emissions from bait fishing	Wharf Operating Restaurants Transport	521.55
Upstream and Downstream Emissions	Category 1a: Purchased goods and services, emissions from bait transport	Bait	581.31
Upstream and Downstream Emissions	Category 1b: Purchased goods and services, emissions from vessels used in lobster fishing	Bait	4,727.39
Upstream and Downstream Emissions	Category 1c: Emissions from electricity used at wharves	Fishing	84.52
Upstream and Downstream Emissions	Category 1d: Emissions from purchased ingredients	Wharf Operations	429.38
Upstream and Downstream Emissions	Category 3: Fuel- and energy-related activities not included in Scope 1 or Scope 2	Ingredients	2.52
Upstream and Downstream Emissions	Category 4: Emissions from upstream transport between wharves and Luke's properties for lobster and crab delivery	Processing	173.27
Upstream and Downstream Emissions	Category 5: Waste generated in operations	Transport	0
Upstream and Downstream Emissions	Category 9: Emissions from downstream air transport via UPS	Transport	131.86
Upstream and Downstream Emissions	Category 9: Emissions from downstream ground transport via UPS	Transport	0.27
Upstream and Downstream Emissions	Category 9: Emissions from non-UPS downstream transport	Transport	244.41
Total (mt/reporting year):			**7,998.93**

Emissions from the Luke's Lobster Supply Chain for Lobster and Crab Products



BAIT

1,103 CO_2 emissions (mt/yr)

BAIT FISHING **522** CO_2 emissions (mt/yr)

BAIT TRANSPORT **581** CO_2 emissions (mt/yr)

FISHING

4,727 CO_2 emissions (mt/yr)

LOBSTER & CRAB FISHING **4,727** CO_2 emissions (mt/yr)

WHARF OPERATIONS

107 CO_2 emissions (mt/yr)

ELECTRICITY USED **107** CO_2 emissions (mt/yr)

PROCESSING

797 CO_2 emissions (mt/yr)

PROPANE/NATURAL GAS LOBSTER STEAMERS **546** CO_2 emissions (mt/yr)

REFRIGERATION **174** CO_2 emissions (mt/yr)

ELECTRICITY AT PROCESSING PLANT **74** CO_2 emissions (mt/yr)

COLD STORAGE FACILITY **3** CO_2 emissions (mt/yr)

TRANSPORT

566 CO_2 emissions (mt/yr)

LOBSTER AND CRAB DELIVERY FROM WHARVES TO LUKE'S **173** CO_2 emissions (mt/yr)

DIRECT TO CONSUMER TRANSPORT: UPS GROUND AND AIR **132** CO_2 emissions (mt/yr)

WHOLESALE GROUND TRANSPORTATION **244** CO_2 emissions (mt/yr)

LUKE'S-OWNED VEHICLES **17** CO_2 emissions (mt/yr)

RESTAURANTS

269 CO_2 emissions (mt/yr)

GAS AND PROPANE AT SHACKS AND RESTAURANTS **85** CO_2 emissions (mt/yr)

ELECTRICITY AT SHACKS AND RESTAURANT **170** CO_2 emissions (mt/yr)

REFRIGERATION AT SHACKS AND RESTAURANTS **14** CO_2 emissions (mt/yr)

INGREDIENTS

429 CO_2 emissions (mt/yr)

PRODUCT INGREDIENTS **429** CO_2 emissions (mt/yr)

FIGURE 1.
Total assessed emissions by operations category

EMISSIONS PER POUND OF LOBSTER AND CRAB

An important figure in comparing the emissions of Luke's products to other protein sources is the pounds of emissions per pound of lobster or crab. This calculation includes all of the operations categories above with the exception of additional ingredients (e.g. buns for lobster rolls), which are more appropriately allocated to final products rather than the overall lobster or crab average. The specific emissions of select Luke's products, including all additional ingredients, are explored in the full report.

Nearly all of the crab that Luke's purchases comes from vessels that exclusively fish crab in Massachusetts. Data show that this fishery is more efficient in fishing fuel usage, the largest source of emissions in the supply chain. As such, it is appropriate to consider the emissions per pound of Massachusetts crab separately from the emissions per pound of lobster/crab caught in the combined fishery in Maine and Nova Scotia, which is predominantly lobster but includes a small percentage of crab.

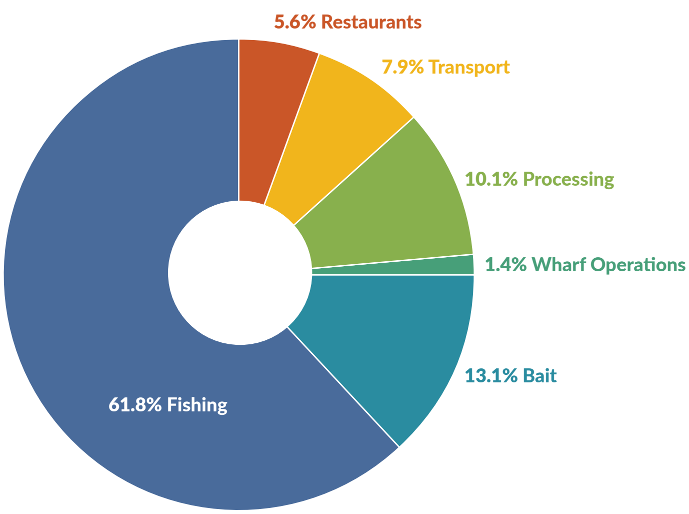


FIGURE 2.
Percentage breakdown of 2.89 lbs of CO2equivalent emissions per lb of Maine/Nova Scotia lobster/crab

Emissions from the Luke's supply chain for lobster (including Maine lobster, Nova Scotia lobster, and a small percentage of Maine crab caught in lobster pots) equates to 0.00131 metric tons, or 2.89 pounds, of emissions per pound of lobster. Emissions from the Luke's supply chain for crab landed in Massachusetts equates to 0.000958 metric tons, or 2.11 pounds, of emissions per pound of crab. The percentage breakdown of these numbers by operations category are presented below.

These values indicate that Luke's lobster and crab have a lower footprint than those available in the literature for other proteins such as beef (60 lbs emissions per lb of protein), lamb (24 lbs per lb), farmed prawns (12 lbs per lb), and pork (7 lbs per lb)[2]. Published comparison studies have historically ranked crustaceans among the highest emissions proteins from wild-caught fisheries, with one study estimating 7.9 lbs of emissions per lb of protein[3]. These studies often consolidate findings from many different fisheries into broad categories such as "crustaceans" which is in stark contrast to Luke's analysis here, which is based on a precise region, a network of known fishers, and the specificity of a single company's operations. Thus, a true "apples to apples" comparison of this study does not exist as a reference point. Rather these global studies can be viewed as general benchmarks against which to consider Luke's products from a relative and approximate standpoint.

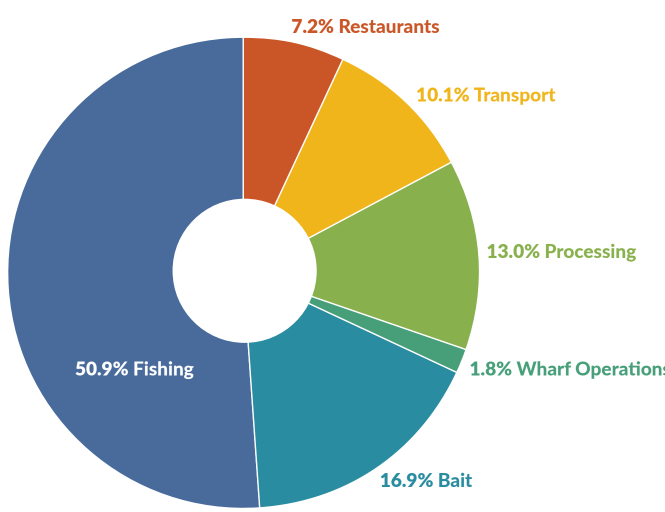


FIGURE 3.
Percentage breakdown of 2.11 lbs of CO2 equivalent emissions per lb of Massachusetts crab

CONCLUSION AND RECOMMENDATIONS

The identification and quantification of the emissions associated with Luke's lobster and crab products has revealed opportunities for emissions reductions. Recommendations for pursuing those reductions are summarized below and elaborated upon in the final section of the report.

Lobster and Crab Harvest - Bait and Fuel Use

As demonstrated in the graphic above, the parts of the supply chain with the highest emissions and greatest opportunities for reduction include bait and fuel used for fishing—items over which Luke's has no direct control. What Luke's does have is a strong relationship with its suppliers, built on mutual understanding and respect. These unique connections can serve as the foundation for improvement, leveraging the recommendations below as a starting point:

Work with the lobster industry on the sources of emissions within their control and options for reduction.

▸ **Fuel Use During Fishing Activities (Current Emissions 4,727 mt - Scope 3, Category 1b):**

- In the near term, this means consideration of using biodiesel as an alternate fuel and potential modification of fishing practices to increase efficiency. Long-term solutions may include use of hybrid electric and electric-powered boats when they become feasible.

▸ **Bait Selection (Current Emissions 1,103 mt - Scope 3, Category 1a and 1b):**

- Promote to fishermen the value of using bait that is domestic, locally-sourced and/or a byproduct of another industry (i.e. discarded fish heads/racks or pig hide).
- Because Luke's is affiliated with a bait company, there is a unique opportunity to influence a significant source of its Scope 3 emissions. By selling bait that is sourced locally and/or a byproduct of another industry, they can put more low-emission bait products into the market and the fishing process.

Wharf Operations

Luke's is well positioned to use its established relationships with wharves to work collaboratively on initiatives that will reduce emissions from wharf operations. These recommendations will not only reduce Luke's GHG emissions but also stand to improve wharves' operational efficiency and reduce costs for suppliers.

▸ **Purchased Electricity at Wharves (Current Emissions 107 mt - Scope 2) Wharves operated by Luke's and Scope 3, Category 1c: all other wharves):**

- Continue to work with wharves to explore switching wharf operations to renewable energy sources such as rooftop or on- premise solar installations, or solar power purchase agreements, and energy efficiency upgrades in all stages of production.

Processing

Because Luke's operates its own processing plant (SeaCo) and the company has direct control over some significant sources of Scope 1 and 2 emissions, processing represents a significant opportunity for emissions reductions. We offer the following recommendations to reduce emissions from processing:

▸ **Natural Gas and Propane (Current Emissions 546 mt - Scope 1, Stationary Combustion):**

- Explore options for switching to renewable natural gas (RNG) for high-emissions processing and steaming equipment when it becomes an option. Until, the company supplying gas to SeaCo, is "actively soliciting RNG program proposals to integrate with our system[4]". Luke's should remain in discussion with utility providers to stay abreast of the development of this program and to advocate for the advancement of RNG supply and credit programs.
- As processing appliances are in need of replacement, explore opportunities to switch from natural gas– and propane- fueled heat sources to low-energy-use electric options.
- Luke's has had early conversations with a wastewater consultant regarding the creation of a biodigestion system to turn processing waste into RNG on-site at SeaCo. This is likely to be a high dollar investment with

a long development time but, if viable, one that should be pursued as a true and reliable source of RNG to power equipment that cannot easily be transitioned to electric, like lobster steamers.

▶ **Gases and Vapors from Appliances**
(Current Emissions 174 mt - Scope 1, Fugitive Emissions):

- As appliances are in need of replacement, replace high GWP refrigerators, chillers, and air conditioning units with units that use low or lower GWP[5] refrigerants.

▶ **Purchased Electricity**
(Current Emissions 74 mt - Scope 2, Purchased Electricity):

- Luke's is already taking significant action to address purchased electricity emissions (Scope 2) by purchasing Renewable Energy Credits (RECs). Partial RECs reduced processing emissions this reporting year by 224 metric tons. Continuing purchasing these RECs throughout a full calendar year is expected to reduce this number to zero in future years.
- As electric appliances and equipment need to be replaced, choose the most energy-efficient replacement option available at that time.

Transport

Both upstream transport of lobster and crab and downstream transport of processed products offer opportunities for emissions reductions. While most aspects of transport are not directly within Luke's control, recommendations below outline ways to work with suppliers to pursue lower-emissions options.

▶ **Downstream Wholesale Distribution**
(Current Emissions 244 mt - Scope 3, Category 9):

- Investigate ways of reducing downstream transport emissions through optimization of shipping schedules and exploring lower-carbon shipping options and/or offsets.

▶ **Upstream Transport**
(Current Emissions 173 mt - Scope 3, Category 4):

- Work with wharves to establish a schedule for enhanced coordination in the transport of lobster and crab to Luke's, such that wharves along the same route transport products together. Concurrently or alternatively, work with wharves to replace transport vehicles with electric vehicles or more fuel-efficient vehicles.

▶ **Direct to Consumer Distribution**
(Current Emissions 132 mt - Scope 3, Category 9):

- Luke's has committed to offsetting emissions from UPS shipments, so this reduction is already planned, but is not reflected in this report because the switch did not take place until 2022. This will represent an emissions reduction of approximately 132 tons. Additional methods of carbon neutral shipping and transport should be routinely explored as part of the ongoing operations optimization process.

▶ **Luke's-Owned Vehicles**
(Current Emissions 17 mt - Scope 1, Mobile Combustion and Scope 1, Fugitive Emissions):

- With respect to Luke's own fleet of vehicles, consider selecting fully electric vehicles at the time of replacement. Consider the truck refrigeration units upon replacement, prioritizing low GWP refrigerants if possible.

Restaurants

Luke's restaurants and shacks represent a relatively small portion of the supply chain emissions, especially since RECs are being used to offset electricity usage at many locations. Still, more progress can be made with the purchase of additional RECs, switches to renewable energy sources, and utilization of more efficient equipment as replacements are required.

▶ **Restaurants/Shacks**
(Current Emissions 267 mt - Scopes 1 & 2):

- All of the recommendations outlined for the SeaCo processing facility should be considered for each restaurant and shack location, albeit on a smaller scale. Transitioning all Luke's properties to RECs or renewables offers the opportunity to offset an additional 97 metric tons.

Ingredients

Product ingredients offer the opportunity for a variety of small, individual choices to add up to significant emissions reductions. By considering the inputs of each product and working collaboratively with ingredient suppliers, Luke's can further reduce its own footprint and encourage and inspire others to do the same.

- **Product Ingredients (Current Emissions 429 mt - Scope 3, Category 1d):**
  - Inform partner manufacturers and ingredient suppliers of Luke's desire to source the lowest-emission ingredients possible and switch where viable.

Organization-Wide Opportunities

This product-level analysis represents an important first step in Luke's journey to achieving net zero emissions and has revealed additional operational improvements that would serve to further inform and empower the company's emissions reduction efforts.

- Some emissions estimates in this analysis have been calculated using proxy values due to the lack of available data. Developing and implementing a comprehensive emissions tracking program and protocols will provide additional data needed to further refine emissions measurement, thereby reducing uncertainty. This will also further enable the completion of Luke's stated desire to conduct a full organizational assessment.
- Complete a full organizational carbon emissions analysis. This report focuses on lobster and crab products and on certain scopes and categories of emissions. Estimates of emissions associated with one Luke's menu or grocery item are therefore not comprehensive, as certain emissions categories (for example employee commuting) are not included.
- The combination of more accurate calculations from more complete data sets and the comprehensive view offered by a full organizational assessment will allow Luke's to analyze where to best concentrate efforts for ongoing reduction efforts by revealing the relative value of all GHG emission–generating activities.

Caveats for the Broader Industry

Luke's Lobster and Island Institute intend for this study to be useful as a basis for others in their industry to have a general understanding of the footprint of their products. However, there are a few important points of differentiation between the Luke's supply chain, studied here, and that of others in the industry that must be accounted for when considering the carbon footprint of lobster and crab from the same regions but sourced through other companies.

- Downstream transportation makes up a relatively small proportion of the carbon emissions identified in this report. It is important to note that virtually all product generated in the supply chain studied here are used domestically. The analysis reflects the delivery of product to Luke's restaurants in the US, to wholesale distribution hubs for retail and wholesale, and overnight to its online market customers within the United States. Luke's engages in very little overnight air freight of live lobster. For other companies, shipping live lobster by overnight air freight is often a primary line of business with shipments traveling as far afield as China. These companies should note that studies have shown air freight emits an estimate of 0.0005 pounds of CO2 equivalent per km traveled per pound shipped[6]. A flight from Boston to Shanghai, for example, would then add 5.87 pounds of emissions to each pound of lobster, roughly tripling the carbon footprint revealed in this study.
- Luke's purchases renewable energy credits to offset the Scope 2 emissions from every facility where they control their electric accounts. This report reflects Luke's having done so for 7 out of their 12 months of operation in 2021. This action reduced their carbon footprint from processing and restaurants by 0.15 pounds per pound of lobster sold. Generally speaking, this action is not a common practice in the lobster industry. Therefore, lobster sourced from companies not doing so will have higher Scope 2 emissions.

INTRODUCTION

Luke's Lobster was founded in 2009 in New York City and has grown to 28 shacks7 and restaurants (including franchises) around the world. This report addresses only company-owned facilities (17 shacks, one restaurant, and the SeaCo processing facility) and related Scope 3 upstream and downstream sources. The company buys lobster and crab from seven wharves in Maine and one wharf in Nova Scotia, Canada. Lobster and crab landed at these wharves are transported to and processed at Luke's Saco, Maine processing plant (also called SeaCo). The majority of the company's crab is purchased from two boats in Massachusetts. That product along with crab purchased from the aforementioned Maine wharves was also processed at SeaCo for the 2021 reporting year. Lobster and other sustainable seafood products are sold at Luke's retail outlets, through branded grocery distribution around the world, and through direct-to- consumer marketing throughout the United States.

Luke's is fully dedicated to conducting business in an environmentally, socially, and economically sustainable manner. As evidence of this dedication, the company has achieved B Corporation certification, a designation that the business is meeting high standards of verified performance, accountability, and transparency on factors from supply chain practices and input materials to employee benefits and charitable giving. The combination of these corporate ethics and the understanding that the lobster industry must contribute to further controlling GHG emissions as a means of combating the impacts of climate change has led to Luke's working toward a goal of net zero business operations through carbon reductions and carbon offsets.[8] As a first step toward accomplishing this ambitious goal, Luke's has undertaken research and assessment of its own GHG emissions related to the sale of two of its primary products - lobster and crab. At the outset, it is assessing emissions from harvest, bait acquisition and use, dock and wharf operations, transportation, processing, distribution, and restaurant operations, all with an eye toward identifying and reducing emissions. Ultimately, Luke's plans to assess the totality of its operations, reduce GHG emissions to the greatest extent feasible, and acquire carbon offsets to achieve the company's goal of zero GHG emissions.

To begin this journey, Island Institute, on behalf of and in partnership with Luke's, commissioned Council Fire, a global sustainability consultancy, to conduct this initial assessment of GHG emissions. Council Fire obtained specific information on GHG emissions and energy use from utility records, receipts, and interviews with people throughout the company's supply chain. Where information was not available, proxies from similar supply chain operations were used.

The results of this research have provided valuable information which serves as the basis for a series of recommendations for Luke's to consider in further reducing emissions. Ultimately, it is expected that the carbon reduction activities selected for implementation will be determined by cost, availability of GHG-reducing technologies, and which options are subject to greater control by Luke's (e.g. equipment such as chillers, freezers, aeration systems, and processing equipment at wharves, processing facilities, and restaurants vs. supply chain waypoints such as harvesting operations which will require fishermen engagement and acceptance of changes proposed to vessel and fishing operations).

EMISSIONS SCOPE

GHG emissions occur in the operation of companies and production of goods. Emissions are divided into three “scopes.”

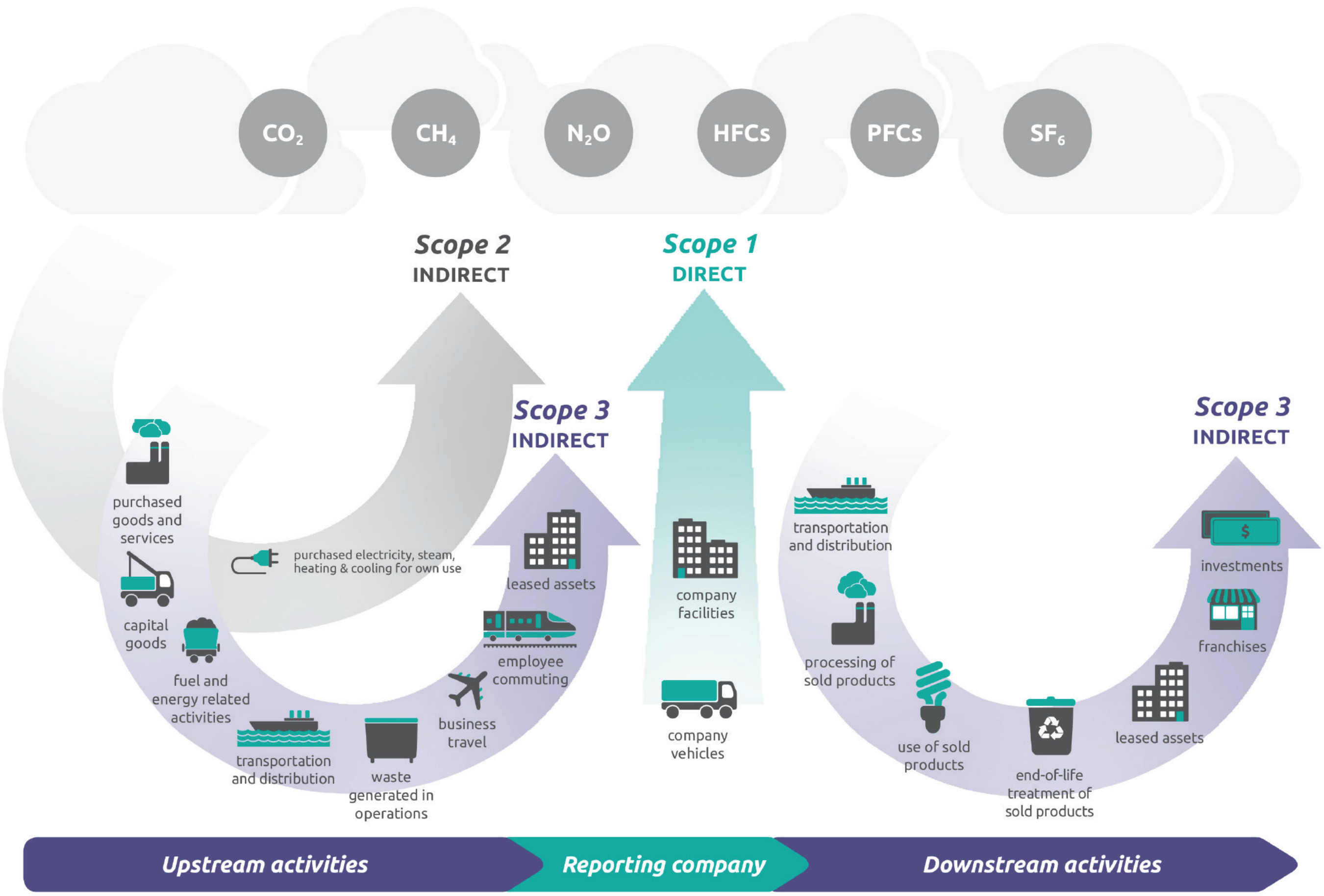


FIGURE 4.
GHG Protocol Scopes and Emissions, image credit WRI/WBCSD

Scope 1 emissions are considered “direct,” meaning they result from activities conducted by the reporting company at or with company-owned or company-controlled properties/equipment.

According to The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard[9], Scope 1 emissions for non-energy, -metal, -chemical, -mineral, -waste, -pulp and paper, -fluorocarbon, or -semiconductor sectors should include:

- Stationary combustion,
- Mobile combustion, and
- Fugitive emissions (mainly hydrofluorocarbon, or HFC emissions, during use of refrigeration and air-conditioning equipment)

Emissions in Scopes 2 and 3 are considered “indirect,” resulting from locations or assets not owned or controlled by the operating company, but resulting from activities of the reporting company. Scope 2 emissions specifically refer to emissions from purchased electricity. Scope 3 emissions result from upstream and downstream activities related to or supporting the operation of the reporting company.

EMISSION SCOPE	EMISSION CATEGORIES
SCOPE 1	**Direct emissions from facilities and equipment owned or controlled by reporting organization** (All included in report)
	Stationary combustion of fuels at organization locations
	Mobile emissions from the operation of vehicles owned or leased by the reporting company
	Fugitive emissions from refrigeration leakage of greenhouse gas emissions during installation, servicing, operation, and disposal of equipment
SCOPE 2	**Indirect emissions from reporting company**
	Indirect emissions from purchased electricity
SCOPE 3	**Indirect emissions from upstream and downstream activities (*indicates inclusion in report)**
	*Category 1 Purchased goods and services: emissions from extraction, production, and transportation Category 2 Capital goods: emissions from extraction, production, and transportation *Category 3 Fuel and energy: emissions from extraction, production, transmission, and transportation *Category 4 Upstream transportation and distribution of purchased products *Category 5 Disposal and treatment of waste from business operations Category 6 Business travel in vehicles not owned or leased by the reporting company Category 7 Employee commuting Category 8 Operation of upstream leased assets *Category 9 Downstream transportation and distribution of goods Category 10 Processing, by downstream companies, of products sold by the reporting company Category 11 Use of sold products Category 12 Waste disposal and treatment of products sold by the operating company Category 13 Operation of downstream leased assets Category 14 Operation of franchises Category 15 Operation of Investments

GREENHOUSE GASES INCLUDED

Greenhouse gases included in emissions calculated here are: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These are the greenhouse gases included in greenhouse gas inventory guidance and technical guidance resources (cited in each section, as appropriate) followed during calculations.

Emissions from different greenhouse gases are made comparable to one another through a factor called Global Warming Potential (GWP)10. GWP measures the greenhouse effect of a gas as the amount of energy (or heat) 1 ton of gas will absorb over 100 years, relative to the amount 1 ton of carbon dioxide will absorb. GWPs are used as a multiplier to facilitate adding the emissions of multiple gases together to get overall CO_2 equivalent emissions resulting from a given activity. Gases with high GWP absorb more heat than those with lower GWPs. The GWP of methane (CH_4) is 28, so to convert emissions from methane to CO_2 equivalent emissions, we multiply emissions of CH_4 by 28. The GWP of N_2O is 265.

METHODS AND RESOURCES

The Greenhouse Gas Protocol Initiative (GHG Protocol), developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), provides guidance in quantifying and reporting GHG emissions in their GHG Protocol Corporate Accounting and Reporting Standard[9]. This document does not provide all of the actual mathematical equations required for GHG calculations; rather it provides associated guidance and principles. The GHG Protocol provides tools and guidance documents for emissions calculations for various scopes and categories of emissions for various sectors and countries. The EPA Center for Corporate Climate Leadership provides guidance documents based on the GHG Protocol. Both the GHG Protocol and the EPA Center provide emissions factors and other standard values required for various emissions calculations.

Throughout this project, GHG Protocol guidance documents and emissions factors were used whenever possible. When equations were not available in GHG Protocol documents, EPA Center Guidance Documents were consulted to determine what equations would be included in calculations. Whenever GHG Protocol emissions factors appropriate for specific calculations were available, these were used.

When EPA sources had emissions factors more up-to-date or more specific to calculations being done, they were used. Throughout this report, the documents from which equations and emissions factors were obtained are listed for each scope and category of emissions calculations. In this assessment, we are reporting on the emissions from one year of operation, 2021, using data from that year except when 2021 data were not available. When 2021 data were not available, proxy numbers were used. These numbers were either exact numbers from other years (2020 or 2022) or estimates calculated based on available 2021 or 2020 data. Specifics regarding proxy data used are provided in relevant sections of the report. All reported emissions are in metric tons per operating year.

SCOPE 1 | DIRECT EMISSIONS

Scope 1 emissions, also referred to as “direct” emissions, are those that occur directly from operations owned and/or controlled by Luke’s. These include emissions of the three major greenhouse gases that impact climate: CO2 (carbon dioxide), CH4 (methane), and N2O (nitrous oxide).

Luke’s-owned and controlled facilities included in Scope 1 emissions calculations are the SeaCo processing plant in Saco, Maine, Portland Pier, Luke’s Lobster shacks, and Luke’s-owned vehicles. Emissions from these facilities and assets are calculated in three categories identified by the GHG Protocol10: fugitive emissions, which result from the leakage of greenhouse gases during installation, servicing, operation, and disposal of equipment from refrigeration and air conditioning sources; emissions from stationary combustion, or from the use of fuels at stationary, company-owned and -controlled assets; and emissions from mobile combustion, which result from the operation of company-owned or -controlled vehicles.

SCOPE 1 | DIRECT FUGITIVE EMISSIONS FROM REFRIGERATION[11]

Background

Fugitive emissions are directly released via the installation, operation and leakage, and disposal of refrigerants in refrigeration and air conditioning units, and can be significant sources of GHG emissions. For this reason, they are included in the overall GHG analysis for Luke’s lobster and crab products. Various formulations of refrigerants are used in refrigeration and air conditioning. Different formulations have different GWPs. Refrigerants with higher GWPs impact climate more severely, while those with low GWPs have less of an impact. High GWP refrigerants are frequently used in industrial equipment, but low GWP options are available and becoming more common in the marketplace (see Appendix, Table 26).

General

Luke's prototype restaurant is a small (less than 2,000 square feet), counter service, limited menu lobster shack, that both Luke's and this report refers to as 'shacks.' Luke's operates one larger, full service, expanded menu restaurant in Portland, Maine, that both Luke's and this report refer to as a 'restaurant' or 'Portland Pier.'

Emissions were calculated for all Luke's-owned or Luke's-controlled properties for which data was available, with emissions for each of the following calculated separately:

1. Portland Pier Buying Station (where lobsters are bought from harvesters) and Restaurant,
2. Shacks,
3. The processing plant in Saco, Maine (called SeaCo), and
4. Luke's-owned refrigerated vehicles.

Based on the GHG Protocol, fugitive emissions resulting during "use of refrigeration and air-conditioning equipment" were calculated. Per EPA 202012, installation and disposal emissions can be calculated, but should only be included for equipment installed and disposed of in the reporting period. Since no equipment was replaced or disposed of during 2021, no calculations regarding installation and disposal were performed. Based on guidance from these sources and the data provided, emissions occurring "during use of refrigeration and air-conditioning equipment were calculated."

Equations

Equations used to calculate fugitive emissions were obtained from the EPA Center for Corporate Climate Leadership.

Emissions from operations (Equation 1.1) were calculated for each piece of equipment, then multiplied by the GWP (GWP, Equation 1.2) for the specific refrigerant type used in each piece of equipment.

For Portland Pier, the processing plant, and vehicles, the total emissions estimate was calculated as the sum of emissions from each piece of equipment. For shacks, this estimate was calculated for one "average" shack, then multiplied by the number of shacks for an overall estimate of fugitive emissions from refrigeration across all Luke's shacks.

Equation 1.1.
Emissions from Operation = C × (x/100) × T

Where:
C = refrigerant capacity of the piece of equipment
x = annual leak rate in percent of capacity
T = time in years used during the reporting period
(e.g., 0.5 if used only during half of the reporting period and then disposed).

Equation 1.2.
GHG Emissions = Emissions from Operation × GWP

Refrigerant capacity (C) for each piece of equipment, as well as refrigerant used, was found on the manufacturer's website. Annual leak rate (x) was identified based on type of equipment from Default Emission Factors for Refrigeration (Table 3 in The EPA Center for Corporate Climate Leadership's Fugitive Emissions GHG guidance document[12)]. Time in use (T) was assumed to be one full year, or 1, for each piece of equipment, except when otherwise specified. Global Warming Potential was identified, by refrigerant type, from Table 1 in the GHG guidance document, the Greenhouse Gas Protocol's Global Warming Potential Values datasheet, and the California Air Resources Board's Refrigerant Management Program table (based on IPCC AR4 data).

Data

No equipment was installed, or old equipment disposed of, in the 2021 reporting period. Data collection, calculations, and emissions factors used followed EPA protocols, which are based on The GHG Protocol, as found in "Direct Fugitive Emissions from Refrigeration, Air Conditioning, Fire Suppression, and Industrial Gases".[13]

Data were obtained by:

1. Touring various Luke's-owned facilities and identifying model numbers for refrigeration equipment,
2. Obtaining lists of equipment and amount of time each piece was in use from Luke's employees, the processing plant in Saco, Maine (called SeaCo), and
3. Identifying refrigeration units or similar units by photo (when labels were not clearly visible or equipment was not included in provided lists). Refrigerants used in each unit, and refrigerant capacity per unit, were identified via manufacturer and/or vendor specification sheets. Units included in analyses[14] were those being used by Luke's during data collection (2021).

- **Shacks**
  Data provided by Luke's indicated that each shack, on average, contains four Beverage-Air WTR72AHC-FIP Worktop Refrigerators, one Avantco A-49F-HC 54 Solid Door Reach-In Freezer, and one Avantco A-49RHC Refrigerator. Based on this, fugitive emissions were calculated for an "average" shack and multiplied by the total number of shacks (17) for an overall emissions value. All equipment was assumed to be running/in use for 100% of the year.

- **Portland Pier Wharf (buying station and restaurant)**
  The Portland Pier Wharf includes a buying station and a restaurant. Equipment was inventoried during a walk-through of the facility. Photographs of refrigeration equipment, including labels where possible, were used to guide data collection including refrigerant capacity and refrigerant used for each piece of equipment. Where data were not available for certain pieces of equipment, data for similar equipment were used. For example, some manufacturers do not provide actual refrigerant capacity for certain units, so capacity values from similar equipment were used as proxy. All equipment was assumed to be running/in use for 100% of the year.

- **Processing Plant in Saco, Maine (SeaCo)**
  Equipment was inventoried during a walk-through of the facility. An equipment list provided by Luke's was used to supplement the resulting list. Data provided by Luke's and photographs of refrigeration equipment, including labels where possible, were used to guide data collection including refrigerant capacity and refrigerant used for each piece of equipment. Where data were not available for certain pieces of equipment, data for similar equipment were used. For example, some manufacturers do not provide actual refrigerant capacity for certain units, so capacity values from similar equipment were used as proxy. Equipment was assumed to be running/in use for 100% of the year, except when Luke's provided specific information on hours of use.

- **Refrigerated Vehicles**
  Information on Luke's refrigerated vehicles was provided by the company. These data were used to guide data collection including refrigerant capacity and refrigerant used for each piece of equipment. For one vehicle, data on refrigerant capacity was not available. The capacity of a similar model from the same company was used as a proxy. Luke's provided an estimated number of trips or days in use per year. Time in use was estimated to be 8 hours per trip multiplied by the number of trips.

- **GWPs**
  GWP values for each refrigerant used in Luke's equipment were obtained from the Greenhouse Gas Protocol's Global Warming Potential Values[15] and the California Air Resources Board's list of High GWP Refrigerants[16]. California Air Resources Board (CARB) GWPs were only used when a refrigerant was not listed in the Greenhouse Gas Protocol's document. The CARB is a recognized leader and reliable source of carbon emissions related information. Following the CARB, we consider (in the table and discussion below) refrigerants with a GWP greater than 150 to be "high GWP refrigerants." See Appendix Table 26 for details.

Results

All units are in metric tons per operating year. The majority of fugitive emissions from operation of refrigeration and air conditioning comes from SeaCo (91.67%), followed by Portland Pier (7.25% of emissions), refrigerated vehicles (1.07% of emissions), and shacks (<1% of emissions). A summary table and chart are provided below, Table 3. SeaCo's high emissions come from the use of many large refrigeration units, all of which use high GWP refrigerants. The details of this can be found in Appendix Tables 27 - 30, which list emissions from individual refrigeration/air conditioning units from each location.

Table 3: Scope 1 Fugitive Emissions Summary Table (All units are in metric tons/reporting year)

Location/Type	Operations Category	C02 Emissions (mt/yr)	Percentage of Scope 1 Fugitive Emissions
Shacks	Restaurants	<0.01	0.004%
Pier	Restaurants	13.79	7.25%
SeaCo	Processing	174.35	91.67%
Vehicles	Transport	2.04	1.07%
TOTAL		**190.18**	

SCOPE 1 | DIRECT EMISSION FROM STATIONARY COMBUSTION SOURCES

Background

Emissions from stationary combustion result from the combustion of fossil and non-fossil fuels[17], often for the purposes of heating. While most of these emissions are CO2, some emissions also occur in the form of CH4, and N2O. Emissions factors vary among fuels, with emissions factors from natural gas being lower than from solid fossil fuels. Stationary combustion emissions are primarily from heating activities.

Emissions were calculated separately for natural gas at the following Luke's locations 1) SeaCo (Saco, Maine), 2) Portland Pier, 3) FiDi (26 S William St, New York), 4) SoMa (92nd St., San Francisco), 5) Upper East (242 E 81st St, New York), and 6) Upper West (426 Amsterdam Ave, New York), and for propane at SeaCo. All data collection, calculations, and emissions factors used followed protocols from EPA Center for Corporate Climate Leadership's Stationary Combustion Greenhouse Gas Inventory Guidance GHG guidance document[18]. Data was unavailable for some shacks that are heated with gas (Brickell City Centre in Miami, City Hall in Chicago, and the Las Vegas location). Emissions estimates were calculated for these locations by 1) calculating the average therms of gas per square foot of restaurant used annually to heat Soma and Portland Pier, and 2) multiplying this number by the square footage of each shack with missing data. Following this, all calculations listed below were applied to all of these locations.

Equation 1.3, below, was used to calculate GHG emissions. Emissions were calculated separately for natural gas and propane.

Equation 1.3.
Emissions = Amount of Fuel Used × Emissions Factor

Equation 1.4.
Heat Content = Volume of Fuel × Calorific Value (or HHV)

Because emissions factors were provided in kg/scf and data were provided in Therms, data were converted to scf (standard cubic feet) before calculations were performed. Emissions factors were obtained from EPA's 2018 Greenhouse Gas Inventory Guidance document entitled "Direct Emissions from Stationary Combustion Sources.[19]"

Data

For most locations with data, monthly natural gas bills were provided from 2021. The SeaCo location is serviced by three utility accounts. Luke's provided data in the form of bills for all three accounts; January-October data were from 2021, and November and December data were from 2020. Bills were available in Secure Energy Building Utility Data Analytics (BUDA) for additional locations (listed above) for 2021. Fuel delivered was reported in Therms. Emissions Factors for natural gas were sourced from Table A-1 in EPA Center for Corporate Climate Leadership's Stationary Combustion Greenhouse Gas Inventory Guidance GHG guidance document.

Propane bills were provided for SeaCo from January through December 2020 for two accounts. Emissions Factors for propane were sourced from Table A-1 in EPA Center for Corporate Climate Leadership's Stationary Combustion Greenhouse Gas Inventory Guidance GHG guidance document.

Results

Table 4: Scope 1 Stationary Combustion (All emissions reported in metric tons/reporting year)

Location	Therms Used	Fuel Type	Total CO2 Equivalent Emissions (mt/yr)
SeaCo, ME	91,844	Natural Gas	434.71
Portland Pier, ME	10,406	Natural Gas	55.27
Brickell City Centre, FL	913*	Natural Gas	4.85
City Hall, IL	1,506*	Natural Gas	8.00
FiDi, NY	12**	Natural Gas	0.06
Las Vegas, NV	401*	Natural Gas	2.13
SoMa, NY	218	Natural Gas	1.15
Upper East, NY	39**	Natural Gas	0.21
Upper West, NY	2,509	Natural Gas	13.33
SeaCo, ME	n/a	Propane	111.00
TOTAL			**630.71**

*Indicates proxy value **Indicates a shack that does not use fuel for heating - small values are cooking or miscellaneous use

SCOPE 1 | DIRECT EMISSION FROM MOBILE COMBUSTION SOURCES

Background

Like stationary combustion, mobile emissions occur from the combustion of fuels. Mobile combustion emissions are those from gasoline, diesel, and other fuels used in vehicles. As with stationary combustion, mobile combustion emissions factors vary among fuel types.

General

Emissions were calculated separately for the three vehicles owned by Luke's. Equations and emissions factors were obtained from EPA protocols as found in the EPA Center for Corporate Climate Leadership's Greenhouse Gas Inventory Guidance document entitled "Direct Emissions from Mobile Combustion Sources"[20].

Equations

Emissions from transport are calculated differently for CO2, CH4, and N2O. Calculations for CO2 are based on volume of fuel use, while those for the CH4, and N2O are based on distance traveled. Following this convention, emissions of CO2 from mobile transport were calculated using Equation 1.5 below, and fuel consumption data and emissions factors from Table A-3: Emission Factors for Equation 1.6 (EF2) following protocols from Direct Emissions from Mobile Combustion Sources (Equation 1.5). Emissions of CH4, and N2O were calculated using Equation 1.6 below, and mileage data and emissions factors following protocol in the same source.

The volume of fuel used was not provided for the 2014 Hino Model 195 or the 2011 Mercedes Sprinter. Because of this, the amount of fuel used was estimated using distance traveled and mileage per gallon for these vehicle models. The distance in miles traveled was not provided for the Ford Transit T35. Due to this, estimated miles traveled was calculated using the provided amount of fuel used and average mileage per gallon for this vehicle make and model.

Equation 1.5.
Emissions = Fuel × EF

Where:
EF = Emission factor per volume unit

Equation 1.6.
Emissions = Distance traveled × EF

Where:
EF = Emission factor per distance traveled

Data

Data for three vehicles were provided by Luke's, as follows:

- 2014 refrigerated Hino Model 195: Estimated annual miles traveled
- 2011 refrigerated Mercedes Sprinter: Estimated annual miles traveled
- 2016 Ford Transit T35: Amount of fuel used

For CO2 emissions calculations, the amount of fuel used for the 2014 and 2011 vehicles was estimated based on provided mileage traveled and on mpg values available on vehicle dealer websites. For CH4 and N2O emissions calculations, mileage traveled was estimated based on the provided amount of fuel used and on mpg values available on vehicle dealer websites.

Results

Table 5: Scope 1 Mobile Combustion Emissions (All emissions reported in metric tons/reporting year)

Vehicle	Miles Traveled	Total CO2 Equivalent Emissions (mt/yr)
2014 refrigerated Hino Model 195	11,721	11.75
2011 refrigerated Mercedes Sprinter	4,220	2.389
2016 Ford Transit T35	1,013*	0.67
TOTAL		**14.81**

* indicates an estimate based on volume of fuel used

SCOPE 1 | SUMMARY OF RESULTS

Table 6: Scope 1 Emissions Summary (All emissions reported in metric tons/reporting year)

Category or Type of Emissions	Operations Category	Total CO2 Equivalent Emissions (mt/yr)
Fugitive Emissions (Shacks)	Restaurants	0.01
Fugitive Emissions (Portland Pier Restaurant and Station)	Restaurants	13.79
Fugitive Emissions (SeaCo)	Processing	174.35
Fugitive Emissions (Vehicles)	Transport	2.04
Stationary Combustion (Natural Gas, Shacks)	Restaurants	29.73
Stationary Combustion (Natural Gas, Portland Pier Restaurant)	Restaurants	55.27
Stationary Combustion (Natural Gas, SeaCo)	Processing	434.71
Stationary Combustion (Propane, SeaCo)	Processing	111.00
Mobile Combustion	Transport	14.81
TOTAL		**835.70**

SCOPE 2 | INDIRECT EMISSIONS

SCOPE 2 | INDIRECT EMISSIONS FROM PURCHASED ELECTRICITY

Background

Scope 2 emissions occur from the generation of electricity that is then purchased by Luke's. While not directly emitted by Luke's, indirect emissions from purchased electricity occur as a result of Luke's operations and must therefore be accounted for according to the GHG Protocol and EPA Greenhouse Gas Inventory Guidance. Calculations shown here are based on the purchase of electricity over past years, during which time the electricity use of some locations during some months was matched with Renewable Energy Certificates (RECs). Emissions for sites with RECs[21] contributed zero emissions to the calculated total for months in which the REC was implemented. Emissions in the coming years will be reduced if renewable energy is used year-round.

General

Emissions from purchased electricity were calculated for shacks, the Portland Pier location, and other Luke's-owned facilities. Equations were obtained from EPA protocols as found in "Indirect Emissions from Purchased Electricity."[22]

Equations

Emissions factors (EF) are location- and electricity-source specific. To determine EFs for each location, the eGRID region was identified using the EPA Power Profiler tool[23]. Emissions factors for eGRIDs were available from the eGRID summary tables[24] released by the EPA on 2/23/2021. The emissions factor for renewable energy, when a REC is provided, is 0. Many locations had RECs implemented halfway through the year, so their emissions after implementation of the RECs calculates to 0 for those months.

Emissions estimates were calculated for shacks and restaurants and other properties using the following equation:

Equation 2.1.
Emissions = Electricity × Emissions Factor

Where:
Electricity = Quantity of electricity purchased
EF= CO2, CH4, or N2O emission factor

Data

Electricity usage data: Generally, electricity usage in kWh was available, by account, location, and month, in a summary data format (based on electric bills) in Secure Energy Building Utility Data Analytics (BUDA). Data were not available for all months for all locations. In some instances, electricity usage was reported as "0", rather than N/A, when a bill was missing. In these cases, and in cases where no data were available, the following methods were used to estimate electricity usage.

- For most locations (or account numbers) where data were missing for November and December of 2021, available data from November or December of 2022 were used as proxies for November and December 2021 data.
- For locations (or account numbers) with data missing for some months but available for others, the average kWh used in months with data was used as a proxy for months without data.
- For locations (or account numbers) where no data were available at all, the average kWh per square foot by year and location type (shack or plant) was multiplied by the square footage of that location.

Results

Table 7: Scope 2 Emissions Summary (All emissions reported in metric tons/reporting year)

Location Type	Operations Category	kWh Used	Total CO2 Equivalent Emissions If RECs had Not Been Implemented (mt/yr)	Total CO2 Equivalent Emissions Avoided by Implementing RECs (mt/yr)	Total CO2 Equivalent Emissions, Net After RECs (mt/yr)	Anticipated Additional CO2 Equivalent Emissions to be Avoided Through RECs in Next Year (mt/ yr)
Portland Pier Restaurant	Restaurants	295,200	71.366	51.66	19.71	19.71
Shack Locations	Restaurants	641,929	256.70	106.59	150.11	53.12
SeaCo	Processing	1,230,920	297.58	223.73	73.85	73.85
Fishing Wharf	Wharf Ops	95,465	23.08	0.00	23.08	23.08
TOTAL		**2,263,514**	**648.73**	**381.98**	**266.75**	**169.76**

It should be noted that Luke's figures of 2.89 lbs of emission per lb of lobster/Maine crab and 2.11 lbs emissions per lb of Massachusetts crab is reflective of RECs purchased to offset electricity use in all 22 possible Luke's-controlled restaurant and processing facilities for a portion of the reporting year. These RECs equated to 381.98 metric tons of emissions, or 0.15 lb per lb of lobster/crab. A table detailing Scope 2 emissions by location can be found in the Appendix, Table 32.

SCOPE 3 | UPSTREAM AND DOWNSTREAM EMISSIONS

Scope 3 emissions are indirect emissions that occur upstream and downstream in the company value chain. Upstream emissions are related to goods and services a company purchases, and downstream emissions are related to goods and services the company sells. These emissions are broken into 15 categories. The categories of Scope 3 emissions assessed here are: Category 1: Purchased goods and services, Category 3: Fuel– and Energy–related activities not included in Scope 1 or Scope 2, Category 4: Upstream transportation and distribution, Category 5: Waste generated in operations, and Category 9: Downstream transportation and distribution. These categories and associated calculations are described below, along with reasoning for the exclusion of the other categories.

Upstream and Downstream Emission Sources Measured in this Report:

CATEGORY 1 **Purchased goods and services**	CATEGORY 3 **Fuel- and energy- related activities not included in Scope 1 or Scope 2**	CATEGORY 4 **Upstream transport and distribution**	CATEGORY 5 **Waste generated in operations**	CATEGORY 9 **Downstream transportation and distribution**
• Bait fishing • Bait transport • Fishing (fuel use) • Electricity use at non-Luke's controlled wharves • Ingredients in products and menu items	• Electricity use at storage facility	• Transport of lobster and crab from wharves to Luke's facilities	• Treatment of waste generated at SeaCo	• Transport of products to shacks, grocery, and other locations • Direct to consumer transport of products by air • Direct to consumer ground transport of products

SCOPE 3 ▶ CATEGORY 1 ▶ PURCHASED GOODS AND SERVICES

This category includes emissions associated with the production of products used by Luke's. We account specifically for GHG emissions associated with a) the fishing and transport of bait used in lobster and crab fishing, b) fishing for lobster and crab in fisheries where the two are caught together by the same means, and crab in exclusively crab fisheries, c) electricity use at wharves where lobster and crab are caught, and d) the production of the ingredients in Luke's menu items and other sold products.

Emissions associated with bait used in lobster and crab fishing include emissions from both catching and transporting bait. Emissions from fishing are based on fuel used to fish for lobster and crab. For both emissions from fuel use 23 in fishing and emissions from electricity use at non-Luke's controlled wharves, emissions from fisheries catching only crab were calculated separately for those that catch lobster or both lobster and crab. Menu item emissions only included emissions from the production of ingredients, and omitted emissions from the transport of ingredients to point of sale to Luke's because transport data were inconsistently available.

CATEGORY 1A: EMISSIONS FROM BAIT

Background

Various bait products are used in the fishing of lobster and crab. These include fish species caught specifically for bait (e.g., skates caught in Reykjavik, Iceland), invasive fish species targeted for bait (e.g., Asian carp in Benton, Kentucky), byproducts from fisheries targeting particular species (e.g., tuna heads from tuna fisheries in Vietnam and South Korea), and byproducts from farming (e.g., pig hide from Maine). Emissions associated with bait primarily come from catching and transporting the bait from the location where it is landed to where it is used to fish.

Data

Data on the exact type and amount of bait used to catch the lobster and crab purchased by Luke's in one year were not available, so a proxy was developed. Proxy data were obtained by Luke's from its affiliated bait company, which Luke's recommended to use for calculations as a good proxy for the mix and proportions of different bait types used by the lobstermen that Luke's purchases from. These data were used to estimate emissions, per pound of bait, from both fishing and transport of bait. For most types and species of bait purchased and sold by the company, the following data were provided: pounds of bait, location from which bait is sourced, how bait is transported to the company, the average pounds per load of bait transported, and whether each bait item is fished specifically for bait, or is a byproduct of another fishery or farming operation. Data on emissions from fisheries for each type and species of bait, except Asian carp, were available from scientific literature.

Analyses

Emissions resulting from i) fishing for and ii) transporting each type of bait, by volume, were calculated. Luke's stated that the proportion of each type of bait sold by the bait company is an appropriate proxy for the proportion of each type of bait used to fish for lobster. After consultation with various lobster and crab fishermen, it was estimated that the ratio of bait to lobster or crab caught is 1:1; it is assumed that a pound of bait is used for every pound of lobster or crab caught. Therefore, emissions calculated (for both i) bait fishing and ii) transport) for each type of bait were averaged and weighted by weight of bait (as reported by Luke's) to obtain the average amount of CO2 equivalent emissions from one pound of bait. This value was multiplied by the total weight of lobster and crab processed by Luke's for an estimate of overall emissions from i) catching and ii) transporting bait.

BAIT FISHING

Equations

Following the GHG Category 1 Hybrid method, emissions from fishing bait were calculated using the fuel use equation (3.1) that is used to calculate emissions from mobile transportation in Scope 1 analyses.

Equation 3.1.
Emissions = Fuel × EF

Where:
Fuel = volume of fuel combusted
EF = the CO2 emission factor per mass or volume unit

Analyses: Bait Fishing

The average kg of CO2 equivalent emissions per kg of fish for three types of bait (skate from New Bedford, MA, rockfish from the genus *Sebastolobus* from Seattle, WA, and cod heads from New Bedford, MA) were found in the literature. These numbers were multiplied by the kg of each type of bait fish caught used to obtain total emissions from fishing those species of bait. For all other types of bait except Asian carp and pig hide, published values for the average liters of fuel were available in the literature and used to calculate emissions. The equation above was used to calculate the total amount of CO2 emitted for each type of bait.

The sum of all CO2 emissions was divided by the total weight of bait to obtain the average CO2 emissions per lb of bait. This number was multiplied by the total pounds of lobster and crab processed by Luke's in one year, given the 1:1 ratio of bait: lobster or crab.

Emissions resulting from fishing for bait types that are byproducts of other fishing or farming activities were calculated, but were NOT included in calculations for the overall emissions from bait fishing. This is because these products are not primarily fished for bait, and emissions would presumably occur regardless of their use by the lobster fishery. Their use by the lobster industry is a secondary use. Data on fuel used for catching Asian carp were not available so an estimated emissions value is not assigned, but capture of this invasive species is ecologically beneficial and therefore the use of the fish as bait is treated as a byproduct. Similarly, a value could not be calculated for pig hide as bait, but it is a beneficial use of a byproduct and as such does not contribute to the bait emissions total.

Results: Bait Fishing

Table 8: Bait Fishing Results
(Emissions from fishing of bait purchased by the bait company, used to estimate average emissions per lb of bait and multiplied by lbs of lobster and crab purchased by Luke's in one calendar year)

Bait Type	Source Location	Pounds of Bait Sold	Total Fishing CO2 Emissions in Metric Tons; Bait Included in Total (mt/yr)	Total Fishing CO2 Emissions in Metric Tons; Byproducts Not Included In Total (mt/yr)
Pogeys	Gulf of Maine/Cape May, NJ	2,019,750	87.14	
Redfish Racks	Reykjavik, Iceland	250,000		64.38
Redfish Heads	Reykjavik, Iceland	695,000		178.97
Skate	New Bedford, MA	6,500	7.08	
Skate	Reykjavik, Iceland	6,500	2.02	
Herring	New Brunswick, Canada	37,500	1.01	
Herring	Reykjavik, Iceland	37,500	3.99	
Pig Hide	Northern Maine	233,192		n/a
Asian Carp	Benton, Kentucky	700,000		n/a
Tuna Heads	Vietnam	17,500		8.87
Tuna Heads	South Korea	17,500		8.87
Rockfish (*Sebastolobus*)	Seattle, Washington	205,000	223.17	
Codheads	New Bedford, MA	14,000		10.80
	Total	**4,239,942**	**324.41**	**>271.88**
	Emissions per Pound of Bait		**.0000765**	

Table 9: Bait Fishing Total C02 Emissions (All emissions reported in metric tons/reporting year)

CO_2 Emissions per Pound of Bait (mt)	Pounds of Lobster & Crab Purchased by Luke's	Total CO_2 Emissions (mt/yr)
.0000765	6,816,434	521.55

BAIT TRANSPORT

Equations

Following the GHG Category 1 Hybrid method, emissions from transporting bait were calculated using the fuel use equation (3.2) that is used to calculate emissions from mobile transportation in Scope 1 analyses.

Equation 3.2.
Emissions = distance of transport of material × mass or volume of materials ×emissions factor for the vehicle type

For ocean freight transport emissions calculations, the distance of transport of material was considered to be the distance of ocean freight routes from the origin port to either the port of Boston or the Port of Portland, Maine (as designated by Luke's), from where most bait from the bait company is trucked. When the exact port from which bait is transported was not provided, it was assumed to be the largest fishing port in the city or country of origin as indicated by Luke's. Distance of ocean freight routes was obtained from ports.com (2022), a world seaport marketplace and information hub.

For trucking emissions calculations, the distance of transport of material was considered to be the driving distance (using Google Maps) from either the Port of Boston or the Port of Portland, Maine (as designated by Luke's) to the bait company. Transport from the bait company to individual wharves was not included because data on the number of trips made between wharves and the bait company were not available.

The mass of materials was considered to be the average pounds per trucking or shipping load transported, provided by Luke's.

Analyses: Bait Transport

Emissions were calculated separately for CO_2, CH_4, and N_2O. CH_4 and N_2O emissions were then multiplied by their GWP factors (265 for N_2O and 28 for CH_4) to convert them to CO_2 equivalent emissions, then summed with CO_2 emissions for overall GHG emissions.

Because bait is transported by both ocean freight and trucking, emissions from each of these modes of transport were calculated separately for each bait type, then summed for the overall emissions generated from transportation of each bait type. Emissions were calculated for one transport trip, using weight per load. These emissions were then multiplied by the number of trips, which was estimated by dividing the total weight of each bait type purchased by the average weight per load transported, both of which were provided by Luke's.

The sum of all CO_2 emissions was divided by the total weight of bait to obtain the average CO_2 emissions per lb of bait. This number was multiplied by the total pounds of lobster and crab processed by Luke's in one year, given the 1:1 ratio between bait and lobster or crab. Emissions resulting from transporting bait types that are byproducts of other fishing or farming activities were included in calculations for the overall emissions from bait transport.

Results: Bait Transport

Table 10: Bait Transport (Emissions from transport of bait to the bait company, used to estimate average emissions per lb of bait and multiplied by lbs of lobster purchased in one calendar year)

Bait Type	Source Location	Pounds (lbs)	Ocean Freight Distance per Trip (miles)	Ground Transportation Distance per Trip (miles)	Total CO2 Equivalent Emissions for One Year (mt)
Pogeys	Cape May, NJ	1,514,813	0	539	88.39
Pogeys	Gloucester	504,937	0	176	9.62
Redfish Racks	Reykjavík, Iceland	250,000	3,130	71	20.03
Redfish Heads	Reykjavík, Iceland	695,000	3,130	71	52.08
Skate	New Bedford, MA	6,500	180	179	0.68
Skate	Reykjavík, Iceland	6,500	3,130	71	2.19
Herring	New Brunswick, Canada	37,500	4,086	179	5.73
Herring	Reykjavík, Iceland	37,500	3,130	71	4.01
Pig Hide	Northern Maine	233,192	0	59	1.45
Asian Carp	Benton, Kentucky	700,000	0	1,357	103.74
Tuna Heads	Vietnam	17,500	14,935	179	16.53
Tuna Heads	South Korea	17,500	16,380	179	18.04
Rockfish (Sebastolobus)	Seattle, Washington	205,000	8,406	179	38.88
Codheads	New Bedford, MA	14,000	180	179	0.23
		4,239,942	**56,687**	**3,489**	**361.59**
				Transportation Emissions per Pound of Bait (mt):	**0.0000852**

Table 11: Bait Transport - Total CO2 Emissions (All emissions reported in metric tons/reporting year)

CO2 Emissions per Pound of Bait (mt)	Pounds of Lobster & Crab Purchased by Luke's	Total CO2 Emissions (mt/yr)
.0000852	6,816,434	581.31

OVERALL RESULTS: BAIT FISHING AND TRANSPORT

Table 12: Bait - Overall Emissions Results (All emissions reported in metric tons/reporting year; total emissions is calculated as the emissions per lb of bait multiplied by the total lbs of lobster and crab Luke's purchased)

Bait Emissions From	CO2 Emissions per Pound of Bait (mt)	Pounds of Lobster & Crab	Total CO2 Emissions (mt/yr)
Fishing	0.0000765	6,816,434	521.55
Transport	0.0000853	6,816,434	581.31
Total	**0.0001618**		**1,102.86**

CATEGORY 1B: EMISSIONS FROM LOBSTER AND CRAB FISHING

Background

Category 1 emissions associated with lobster and crab fishing were calculated as the emissions from fuel use in lobster and crab boats during fishing activities. Electricity usage at wharves was calculated separately (see below), but fugitive emissions at wharves were not included because complete data were not available for locations not owned or controlled by Luke's. The majority of emissions associated with lobster fishing are presumed to be from actual fishing activities, particularly from use of fuel in boats. Therefore, calculations included here account specifically for these emissions.

Equations

Following the GHG Category 1 Hybrid method, emissions from catching lobster were calculated using the fuel use equation (3.3) that is used to calculate emissions from mobile transportation in Scope 1 analyses.

Calculations of emissions associated with lobster fishing followed the fuel-based method of transportation emissions calculations:

Equation 3.3.
Emissions = Σ × emission factor for the fuel

Where:
Σ = quantity of fuel consumed)

Data

Data on the amount and type of fuel used in lobster fishing, the total amount of lobster and crab caught, and the amount sold to Luke's were available from four Maine wharves, one wharf in Nova Scotia, and two Massachusetts fishing vessels that only sell crab to Luke's. The total amount of lobster and crab caught at each wharf, and the amount sold to Luke's were available for these wharves. These data were not available for the other three Maine wharves from which Luke's obtains lobster; for these wharves, only data on the amount of lobster and crab purchased by Luke's was available.

Analyses

Emissions were calculated for the wharves and vessels for which complete information was available using the data provided. Emissions for all wharves, which sell either only lobster or both lobster and crab, were calculated separately from those that sell only crab to Luke's due to differences in fishing efficiency (based on recommendations from fishermen). Proxy calculations based only on emissions from wharves (described below) were used to estimate emissions generated by lobster and crab fishing for the other three wharves.

- **Emissions from wharves and vessels with known total catch amounts**
  Emissions from fishing by Massachusetts crab vessels were calculated, and are reported, separately from those from the listed wharves. Using the equation above, the total emissions generated by fishing at each wharf were calculated. For each wharf, emissions for diesel and gasoline were calculated separately, then summed to obtain overall emissions generated by fishing at each wharf. Because emission factors for CO2, N2O, and CH4 differ, emissions of each greenhouse gas were calculated separately for both diesel and gasoline. Emissions of N2O and CH4 were converted into CO2 equivalent emissions, then summed with CO2 emissions to obtain overall CO2 equivalent emissions for each wharf. Luke's does not purchase all lobster and crab caught at each wharf. Therefore, the proportion of all landed lobster and crab purchased by Luke's was calculated for each wharf. This was multiplied by overall emissions from each wharf to determine the emissions at each wharf that should be attributed to Luke's.

- **Emissions from wharves utilizing proxy data**
  It is necessary to account for emissions from the three wharves for which data were incomplete. To do so, the total emissions from the other wharves was divided by the total weight of lobster and crab caught at those wharves. This resulted in the average emissions generated per pound of lobster or crab caught. This number was multiplied by the total weight of lobster and crab Luke's purchased from those wharves to produce an estimate of emissions from each wharf.

Results

To protect industry-sensitive data provided by wharves and vessels, the data and results below are combined. Individual data are known to Luke's and were used for calculations.

Table 13: Emissions from Lobster and Crab Fishing (All emissions reported in metric tons/reporting year)

Wharves and Vessels	Total Gallons of Diesel Sold	Total Gallons of Gas Sold	Proportion of Lobster and Crab Sold to Luke's (average %)	Total CO2 Emissions (mt/yr)
5 wharves with complete data	362,274	9,466	72%	2,543.05
3 wharves utilizing proxy values	-	-	-	1,490.39
2 Massachusetts crab vessels	67,042	0.00	100%	693.96
Total	**>362,281.20***	**>9,466***		**4,727.39**

* actual totals are higher but some data was unavailable; proxy data was used accordingly.

CATEGORY 1C: EMISSIONS FROM ELECTRICITY USED AT WHARVES

Background

Following the GHG Category 1 Hybrid method, emissions from purchased electricity used at wharves were calculated using the Scope 2 equation (3.4) for calculating indirect emissions from purchased electricity.

Equation 3.4.
Emissions = Electricity × EF

Where:
Emissions = Mass of CO_2, CH_4, or N_2O emitted
Electricity = Quantity of electricity purchased
EF = CO_2, CH_4, or N_2O emission factor per unit of electricity purchased

Emissions factors (EF) are specific to geographical regions. The EF for the United States New England Region, termed the "NEWE" region in the EPA Power Profiler Tool, was applicable to and used for all wharves except the one in Nova Scotia. For calculations of the Nova Scotia wharf emissions from electricity, an emissions factor was calculated based on the most recent data available regarding Nova Scotia's GHG emissions per unit of electricity generated (from the Canada Energy Regulator, 2020 data[25]).

Data

Electricity data was only available from the Luke's-operated wharf. Through discussion with Luke's, it was decided that emissions from this wharf would be used to estimate electricity-related emissions from all other wharves from which Luke's sources lobster and crab. Data from the Luke's-operated wharf included the kilowatt hours (kWh) of electricity used during in 2021.

Analyses

Emissions from the Luke's-operated wharf were calculated using the equation above and the CO_2 equivalent emission factor provided by the EPA. Total emissions from each wharf were assumed to be equivalent to total emissions from the Luke's-operated wharf. Because Luke's does not purchase all of the lobster and crab caught at each wharf, the proportion of lobster and crab Luke's purchases from each wharf was multiplied by the assumed total emissions from each wharf. For each wharf, the resulting value is the estimate of emissions from purchased electricity. To calculate an estimate of total purchased electricity emissions from non-Luke's controlled wharves, the estimated emissions from each wharf, excluding the one operated by Luke's, was summed. The Luke's-operated was not included in the overall estimate because it is controlled by Luke's and therefore already accounted for in Scope 2.

Results

To protect industry-sensitive data provided by wharves and vessels, the data and results below are combined. Individual data are known to Luke's and were used for calculations.

Table 14: Emissions from Electricity Used at Wharves Not Accounted for in Scope 2 Results (All emissions reported in metric tons/reporting year)

Summarized Wharves	Lobster and Crab Sold to Luke's (lbs)	Average Proportion of Total Lobster and Crab Caught that is Sold to Luke's	Total CO_2 Equivalent Emissions (mt/yr)
7 non-Luke's controlled wharves	5,030,834	80%	**84.52**

CATEGORY 1D: EMISSIONS FROM PURCHASED INGREDIENTS

Background

Luke's produces a variety of products that include ingredients other than lobster and crab. Emissions generated from the production of these ingredients are estimated here. Because it was not possible to conduct GHG inventories for all companies that generate ingredients used by Luke's, data on emissions for each ingredient were sourced from the literature and from organizations that conduct these calculations for food products. Products included in these analyses are: lobster and crab rolls, lobster mac and cheese, lobster bisque, 8 oz frozen cooked lobster claw and knuckle, 8 oz frozen raw lobster tail, lobster BLT, and lobster cakes.

Data

Luke's provided the amount of each ingredient used to produce each menu item above. Data on emissions generated in production of ingredients were from CarbonCloud[26], FoodFootprint[27], Goucher et al. 2017[28], and MyEmissions[29]. To remain consistent across emissions considered, emissions generated in the production (not transport) of each product were used; this is because data regarding transport of ingredients from 31 farm or processing facility to Luke's or Luke's co-packer's facility were inconsistently available. Whenever possible, emissions values specific to the United States were used. When this was not possible, the average of emissions values from across the sources listed above was used. When emissions numbers for a specific ingredient were not available, emissions from production of a similar ingredient were used. For example, numbers were not available for the production of hot dog buns, so emissions from the production of bread were used instead.

Analyses

Analyses were conducted by calculating the emissions associated with each of the non-crustacean ingredients in each menu item. The emissions values (for the appropriate volume of each ingredient) found in the literature were multiplied by the amount of each ingredient in each dish/item. This number was then multiplied by the number of each dish/item sold.

Results

Table 15: Emissions from Purchased Ingredients Results (excluding transportation of ingredients) (All emissions reported in metric tons/reporting year)

Dish	Emissions from Non-lobster Ingredients per Dish or Package (mt)	Number of Units Sold	Total Emissions (mt)
Lobster BLT	0.0006535	8,104	5.30
Lobster cakes (8 oz packages)	0.0001505	507,264	76.33
Frozen raw lobster tails, seasoned (8 oz packages)	0.0000052	945,008	4.88
Frozen cooked lobster claw and knuckle, seasoned (8 oz packages)	0.0000016	2,152,182	3.38
Lobster Bisque (12 oz)	0.0003392	73,196	24.83
Lobster Mac & Cheese (16 oz packages)	0.0014977	130,462	195.40
Lobster Rolls (2, 4, and 6 oz)	0.0001503	537,859	80.86
Crab Rolls (4 and 6 oz)	0.0001503	233,731	35.14
Total			**429.38**

Overall emissions calculations often exclude emissions incurred from the transport of products, post production, to retail destinations or direct to consumer. The table above reflects this, and includes only pre-processing and processing emissions for non-lobster and non-crab ingredients in each listed Luke's product (sold in the online marketplace, in retail stores, and in Luke's restaurants and shacks). It does not include transportation of ingredients to Luke's OR transportation of Luke's products to the end consumer. Emissions on transportation of products to wholesalers, restaurants, and consumers are calculated in Scope 3, Category 9. A discussion of the comprehensive emissions of each product, including lobster/crab ingredients and transport, is included in the Emissions Comparisons portion of the report.

SCOPE 3 ▶ CATEGORY 1 ▶ SUMMARY

Table 16: Scope 3 Category 1 Emissions Summary (All emissions reported in metric tons/reporting year)

Category or Type of Emissions	Operations Category	Total CO2 Equivalent Emissions (mt/yr)
Category 1a: Purchased goods and services, emissions from bait fishing	Bait	521.55
Category 1a: Purchased goods and services, emissions from bait transport	Bait	581.31
Category 1b: Purchased goods and services, emissions from vessels used in lobster and crab fishing	Fishing	4,727.39
Category 1c: Emissions from electricity used at wharves	Wharf Operations	84.52
Category 1d: Emissions from purchased ingredients	Ingredients	429.38
Total		**6,344.15**

SCOPE 3 ▶ CATEGORY 3 ▶ FUEL- AND ENERGY-RELATED ACTIVITIES NOT INCLUDED IN SCOPE 1 OR 2

Most energy and fuel use associated with Luke's is generated at Luke's-owned facilities or in the catching of products Luke's purchases from other sources. Therefore, they are included in Scopes 1 and 2, or in Scope 3 Category 1. One additional source of energy-related activities, not in those Scopes or Categories, is Luke's storage of some products off-site at a third party refrigerated/frozen storage facility in Massachusetts. Emissions generated at this facility and attributed to storing Luke's products are calculated here. Note that a majority of that facility's electricity is generated by rooftop solar panels, and this was factored into our calculation, reducing the emissions attributable to Luke's products. Another storage facility that does not use renewable energy would have generated 6.17 mt/yr of C02 equivalent emissions for the same amount of product, significantly more than shown here.

Equations

Following the GHG Category 1 Hybrid method, emissions from electricity used at the cold storage facility were calculated using the Scope 2 equation (3.5) for indirect emissions from purchased electricity.

Equation 3.5.
Emissions = Electricity × EF

Where:
Emissions = Mass of CO2, CH4, or N2O emitted
Electricity = Quantity of electricity purchased
EF = CO2, CH4, or N2O emissions factor

Emissions factors are specific to geographic region. The EF for the United States New England Region, termed the "NEWE" region as reported in the EPA Power Profiler Tool was used as the storage facility Luke's uses is located in that region.

Data

The total amount of non-solar energy generated via electricity use at the storage facility that is allocated to storing Luke's products was provided.

Analyses

The value provided was multiplied by the appropriate emissions factor, yielding the total emissions from purchased electricity attributable to off-site storage of Luke's products.

Results

Table 17: Fuel-and Energy-Related Activities Not Included in Scope 1 or Scope 2 (All emissions reported in metric tons/reporting year)

Location	Operations Category	kWh of Electricity Used	CO2 Equivalent Emissions (mt/yr)
Cold Storage Facility	Processing	10,410	2.52

SCOPE 3 ▶ CATEGORY 4 ▶ UPSTREAM DISTRIBUTION AND TRANSPORTATION

Data

Luke's provided the distance (one way) between wharves and SeaCo, the weekly number of trips from each wharf to SeaCo to deliver products, and the total weight of lobster and crab purchased from each wharf.

Equations

Following Scope 3 Guidance from the GHG Protocol, emissions from transporting lobster and crab from wharves to SeaCo were calculated using the following equation:

Equation 3.6.
Emissions = mass of goods purchased × distance traveled × emissions factor of transport mode or vehicle type

Analyses

This method of analysis requires calculations to be done for each leg of a trip or transportation event. Because the mass of purchased goods was not available for each individual trip, the total mass (of lobster and crab) transported annually from each wharf was divided by the number of annual trips from that wharf to SeaCo, and this value was used as a proxy for the mass of purchased goods transported per trip. Emissions factors were obtained from the EPA, and vary by vehicle type. Because we did not know the make and model of vehicle used for each trip, emissions factors for Medium- and Heavy-duty Trucks were used.

Emissions were calculated independently for each wharf, based on one representative trip from each wharf to SeaCo. That value was multiplied by the total number of trips from each wharf to SeaCo for an overall estimate of the emissions generated, annually, produced from upstream transport from each wharf. These calculations were performed separately for each of the GHGs considered: CO2, CH4, and N2O. CO2 equivalent emissions for each gas were calculated using the appropriate GWP value, then these numbers were summed for overall GHG emissions from each wharf.

The sum of annual CO2 equivalent emissions across wharves was calculated to provide a total estimate for emissions from upstream transport.

Results

To protect industry-sensitive data provided by wharves and vessels, the data and results below are combined. Individual data are known to Luke's and were used for calculations.

Table 18: Upstream Transportation and Distribution Results (All emissions reported in metric tons/reporting year)

Summarized Transport Locations	Mileage per Year	Weight per Year (lbs)	Total CO2 Equivalent Emissions (mt/yr)
7 Maine, 1 Nova Scotia, 1 Massachusetts	100,798	6,816,434	173.27

SCOPE 3 ▶ CATEGORY 5 ▶ WASTE GENERATED IN OPERATIONS

Background

This category includes emissions from the treatment of waste at non-Luke's-owned facilities. This is waste produced by Luke's operations, but treated off-site. Emissions may include those from solid or wastewater treatment. The GHG Protocol provides an equation for calculating emissions from waste treatment. However, GHG Protocol notes that "Emissions from wastewater are highly variable..." and indicates that companies in food processing should instead follow methods from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 5 Waste[30]. Because the emissions calculated here are from wastewater treatment, IPCC guidelines were followed. Two calculations, described below, were performed to estimate emissions from wastewater.

Because the wastewater emissions equation (Equation 3.7) depends on an emissions factor, and emissions factors (Equation 3.8) are calculated as ranges, emissions were calculated with both the lowest emissions factor and highest emissions factor.

Equations

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 5 Waste provides the following equation for calculating emissions from industrial waste:

Equation 3.7.

Emissions = Σ [(TOW − S)EF − R]

Where:
TOW = total organically degradable material in wastewater
S = organic component removed as sludge in inventory year, kg COD* (Chemical Oxygen Demand)/yr
R = amount of CH4 recovered in inventory year, kg CH4/yr
EF = emissions factor
*COD is a standard parameter used to measure the amount of organic products in wastewater.

EF is calculated using
Equation 3.8

EF = Bo ● MCF

Where:
Bo = maximum CH4 producing capacity, kg CH4/kg COD
MCF = methane correction factor

Default MCFs were used. They are provided in a range. Two MCFs were used, the lowest value in the range and the highest value in the range. This resulted in two different EFs and ultimately two estimates of emissions from wastewater, a high and low estimate. Because the low MCF is the recommended value for use "based on expert judgment by lead authors of" the IPCC Guidelines, the emissions estimate calculated using this factor was used in calculations of overall GHG emissions from Luke's operations.

Data

Luke's provided the total organically degradable material in wastewater, as well as the percent removed as sludge (1%) and the amount of CH4 recovered.

Results

Table 19: Waste Generated in Operations Results (All emissions reported in metric tons/reporting year)

Amount of Organic Material in Waste (mt)	Component Removed as Sludge (mt)	Amount of CH4 Recovered (kg)	High Estimate (EF=0.025) CO2 Equivalent Emissions (mt)	Low Estimate (EF=0) CO2 Equivalent Emissions (mt)
6.89	0.69	0.00	1.71	0.00

SCOPE 3 ▸ CATEGORY 9 ▸ DOWNSTREAM TRANSPORTATION AND DISTRIBUTION

This category includes emissions generated from the transportation and distribution of sold products in vehicles not owned by Luke's. Two categories of emissions are calculated: i) Direct to consumer transport of products by air and ground, and ii) transport of products to shacks, grocery, and other Luke's-owned/operated locations.

DIRECT TO CONSUMER TRANSPORT OF PRODUCTS BY AIR AND GROUND (UPS)

Data

Data on shipments via UPS were limited to the number of shipments made via each UPS transport method (Next Day, Next Day Air, etc) to each geographic zone within the United States, maps showing the extent of each geographic zone, and the average weight of each shipment.

Equations

Equation 3.9.
Emissions = Σ × distance traveled × emission factor

Where:
Σ = mass of goods transported

For Ground shipments, emissions factors for Medium- and Heavy-Duty Trucks, as provided by the EPA Center for Climate Leadership, were used (because emissions factors for these were not provided in the GHG Protocol Cross Sector Tools[31]).

For non-Ground shipments, emissions factors for "Domestic Air" for CO2 and "Aircraft" for CH4 and N2O emissions, as provided in GHG Protocol Cross Sector Tools were used.

Analyses

Total emissions for each shipment, assuming a full cargo load, were calculated using the equation above and values and proxy values described below. Then the estimated proportion (as described below) of the cargo composed of Luke's products was calculated. This value was multiplied by the total emissions to determine emissions attributable to transport of Luke's products.

- **Distance traveled:**
  According to the GHG Protocol, "If the actual transportation distances are not known, the reporting company may estimate downstream distances by using a combination of: Government, academic, or industry publications, Online maps and calculators, Published port-to-port travel distances." Distance traveled was estimated for shipment to each zone by using UPS zone maps and online maps. The distance for shipments to each zone was assumed to be the distance from Saco, Maine to a randomly selected point within each zone.

- **Mass of goods transported:**
  Neither the total weight capacity nor the specific vehicle used for each shipment in which Luke's products were transported were available. Proxy values were selected for total weight, as follows: Total weight of each "Ground" shipment was assumed to be "The average loaded weight of a newer model UPS truck", or 19,500 lbs, as reported in numerous sources[32]. For non-"Ground" shipments, the total weight was assumed to be the volume limit of a cargo 757-200F (72,210 lbs), one of the aircraft used by UPS, as reported by Boeing[33] and UPS[34].

The weight of each individual Luke's shipment was also not available. The weight of each Luke's shipment was assumed to be 7 lbs, which is the average weight of a Luke's package, as reported by Luke's.

Typically, emissions calculations would be done for each leg of each trip transporting products, which would then be summed.

A "leg" is the distance between each stop along a transport route.

Data on transport legs for each shipment were not available, so calculations assumed that each shipment was transported in a single "leg." Data on whether multiple Luke's packages were shipped together were not available, so it was assumed that each Luke's shipment was shipped separately from other Luke's shipments.

Results

Table 20: Shipping Calculations - Air Transport (UPS) (All emissions reported in metric tons/reporting year)

Shipping Method	Destination UPS Zone	Distance Transported per Trip	Weight per Package (lbs)	Number of Packages Shipped	Estimated CO2 Equivalent Emissions (mt) per Package	Total CO2 Equivalent Emissions (mt)
2 day	8	2,674	7	10	0.01	0.14
2 day	6	1,324	7	4	0.01	0.03
2 day	5	926	7	4	<0.01	0.02
3 Day	8	2,674	7	10	0.01	0.14
AK and Hawaii	126	4,208	7	9	0.02	0.20
AK and Hawaii	124	4,208	7	55	0.02	1.25
Next Day Air	8	2,674	7	2,319	0.01	33.44
Next Day Air	7	1,962	7	724	0.01	7.66
Next Day Air	6	1,324	7	1,405	0.01	10.03
Next Day Air	5	926	7	1,922	<0.01	9.60
Next Day Air	4	660	7	1,541	<0.01	5.49
Next Day Air	3	325	7	1,308	<0.01	2.29
Next Day Air	2	172	7	696	<0.01	0.65
Next Day Saver	8	2,674	7	1,938	0.01	27.95
Next Day Saver	7	1,962	7	716	0.01	7.58
Next Day Saver	6	1,324	7	1,179	0.01	8.42
Next Day Saver	5	926	7	1,661	<0.01	8.29
Next Day Saver	4	660	7	1,577	<0.01	5.61
Next Day Saver	3	325	7	1,618	<0.01	2.84
Next Day Saver	2	172	7	243	<0.01	0.23
Total				**18,939**		**131.86**

Table 21: Shipping Calculations - Ground Transport (UPS) (All emissions reported in metric tons/reporting year)

Shipping Method	Destination UPS Zone	Distance Transported per Trip	Weight per Package (lbs)	Number of Packages Shipped	Estimated CO2 Equivalent Emissions (mt) per Package	Total CO2 Equivalent Emissions (mt)
Ground	8	2,674	7	40	<0.01	0.08
Ground	7	1,962	7	19	<0.01	0.03
Ground	6	1,324	7	27	<0.01	0.03
Ground	5	926	7	55	<0.01	0.04
Ground	4	660	7	44	<0.01	0.02
Ground	3	325	7	81	<0.01	0.02
Ground	2	172	7	396	<0.01	0.05
Total				**662**		**0.27**

NON-UPS TRANSPORT (TO SHACKS AND FOR WHOLESALE)

Data

Data on shipments to shacks, grocery, and wholesale markets provided by Luke's included the Route of transport and destination; Distance traveled per trip and total annual distance; Volume, weight, and percent of each shipment made up of Luke's products; and the total weight of each shipment (including Luke's and non-Luke's products). Due to availability of data, emissions incurred from transportation of Luke's products were calculated only to distribution centers where consumers take possession of the products.

If data are available, it is recommended that future emissions calculations include emissions from the transport of products from distribution centers to grocery locations, and from those locations to consumers' homes.

Equations

Equation 3.10
Emissions = Σ × distance traveled × emissions factor

Where:
Σ = mass of goods transported

Emissions factors for "Medium- and Heavy-Duty Trucks," as provided by the EPA Center for Climate Leadership, were used (because all shipments were indicated to be via heavy-duty trucks).

Results

Table 22: Transport Calculation Results - Non-UPS (All emissions reported in metric tons/reporting year)

Route	Distance Transported per Trip	Distance Transported per Trip	Trips per Year	Estimated CO2 Equivalent Emissions (mt) per Shipment	Total CO2 Equivalent Emissions (mt)
SeaCo to Avenel, NJ (Lineage-Woodbridge) for Key Retailer (attribute to wholesale products)	327	29,900	40	1.04	41.55
SeaCo to Boston for East-Coast LL shacks (transfer point, attribute to all shacks)	96	2,300	200	0.02	4.91
Boston to Boston Luke's Shack Locations (last 3rd party leg, attributable to shacks by market)	6	400	104	<0.01	0.17
Boston to NYC Luke's Shack Locations (last 3rd party leg, attributable to shacks by market)	209	800	132	0.10	13.14
Boston to Philadelphia Luke's Shack Locations(last 3rd party leg, attributable to shacks by market)	313	200	104	0.04	4.13
Boston to Washington, DC Luke's Shack Locations (last 3rd party leg, attributable to shacks by market)	450	400	104	0.11	11.89
Boston to Key Broadline Distribution Centers (attributable to shacks by market)	1,502	2,600	4	2.39	9.54
Boston to Key Broadline Distribution Centers (attributable to shacks by market)	988	2,600	4	1.57	6.27
Boston to Key Broadline Distribution Centers (attributable to shacks by market)	2,720	2,600	4	4.32	17.27
Boston to Key Broadline Distribution Centers (attributable to shacks by market)	3,099	2,600	6	4.92	29.52
SeaCo to Boston-area Cold Storage Facilities (for wholesale--not to shacks or online market)	367	17,550	292	0.11	33.37
SeaCo to Other Significant Wholesale Customers (Shipments Originate in Everett, MA) (attributable to total but not to shacks, wholesale, or online market)	2,720	29,900	4	8.64	34.54
SeaCo to Other Significant Wholesale Customers (Shipments Originate in Everett, MA) (attributable to total but not to shacks, wholesale, or online market)	1,507	29,900	4	4.79	19.14
SeaCo to Other Significant Wholesale Customers (Shipments Originate in Everett, MA) (attributable to total but not to shacks, wholesale, or online market)	2,989	29,900	2	9.49	18.98
Totals		**161,700**		**1,004**	**244.41**

Analyses

The method recommended by GHG protocols and utilized here is to use the equation calculated above for the actual distance traveled with Luke's products, which in this case is a one-way trip. Emissions were calculated for one trip per route. These values were then multiplied by the number of trips made along each route. That value was multiplied by the proportion of each shipment made up of Luke's products to calculate the emissions attributable to Luke's from each trip. Emissions for CO2, CH4, and N2O were calculated separately, multiplied by GWP factors, and summed for overall CO2 equivalent emissions.

SCOPE 3 ▶ CATEGORY 9 ▶ SUMMARY

Table 23: Upstream and Downstream Transport Emissions Summary (All emissions reported in metric tons/reporting year)

Shipping Method	Destination	Total CO2 Equivalent Emissions (mt)	CO2 Equivalent Emissions per Mil per Pound (mt/mi/lb)
UPS Air	Direct to consumer	131.86	4.04 × 1011
UPS Ground	Direct to consumer	0.27	1.64 × 1010
Ground Trucking	All other downstream	244.41	1.08 × 1010
Total		**376.54**	

SCOPE 3 | SUMMARY

TABLE 24: Scope 3 Emissions Summary (All emissions reported in metric tons/reporting year)

Scope 3 Category	Operations Category / Represented in Supply Chain	Total CO2 Equivalent Emissions (mt/yr)
Category 1a: Purchased goods and services, emissions from bait fishing	Bait	521.55
Category 1a: Purchased goods and services, emissions from bait transport	Bait	581.31
Category 1b: Purchased goods and services, emissions from vessels used in lobster fishing	Fishing	4,727.39
Category 1c: Emissions from electricity used at wharves	Wharf Operations	84.52
Category 1d: Emissions from purchased ingredients	Ingredients	429.38
Category 3: Fuel- and energy-related activities not included in Scope 1 or Scope 2 (electricity for offsite product storage)	Processing	2.52
Category 4: Emissions from upstream transport between wharves and Luke's properties for lobster and crab delivery	Transport	173.27
Category 5: Waste generated in operations (low end of range is reported)	Processing	0
Category 9: Emissions from downstream air transport via UPS	Transport	131.86
Category 9: Emissions from downstream ground transport via UPS	Transport	0.27
Category 9: Emissions from non-UPS downstream transport	Transport	244.41
Total		**6,896.48**

EMISSIONS COMPARISON

LOBSTER AND CRAB COMPARED TO OTHER PROTEINS

Based on the data provided and calculations described here, one pound of processed Luke's lobster (and Maine/Nova Scotia crab) is associated with 2.89[35] pounds of CO2 equivalent emissions (or 2.89 kg CO2 per kg of lobster). One pound of Massachusetts crab is associated with 2.11 lbs of equivalent emissions. This number includes emissions generated from the capture and transport of bait used in the fishery, emissions from vessels used for fishing, the aspects of upstream and downstream transport calculated within this report, processing emissions, and emissions from restaurants. Emissions from non-seafood product ingredients are not included in these calculations. Among seafood products, the greatest common contributor of carbon emissions comes from fisheries themselves, particularly from fuel expended during fishing. Results in this report follow that trend, both in terms of fishing for lobster and crab, and in fishing for bait used in the fishery.

It should be noted that the studies discussed below differ in specificity from this analysis in several key ways. First, many of the other studies consolidate numbers from dramatically different fisheries worldwide. Within a category such as "crustaceans", for instance, fishing and processing methods can vary greatly between species and between regions of the world. Fishing methods for Maine lobster vary significantly from Gulf of Mexico shrimp trawling and even Australian rock lobster, whose fishing methods include a very fuel intensive "chasing" of lobster from one area to another. To combine such diverse subjects into one average number does not produce a measure that is accurate for any one specific fishery. This is in stark contrast to the very targeted analysis that produced the results reported here for lobster and crab. This analysis is based on a precise region, a network of known fishers, and the specificity of a single company's operations. Thus, a true "apples to apples" comparison of this study does not exist as a reference point. Rather these global studies can be viewed as general benchmarks against which to consider Luke's products from a relative and approximate standpoint.

Additionally, when comparing global estimates of CO2 emissions from various proteins it is important to closely consider which scopes and aspects of the supply chain are being reported in each instance. Recent estimates of emissions from various fisheries based solely on fuel burned during fishing show lower emissions per kg of protein—for example Parker et al. 2018[36] found global fisheries to have 2.2 kg of CO2 equivalent emissions per kg of protein. This study showed the range of emissions from seafood products to be 0.2 to 7.9 kg of CO2 equivalent emissions per kg, with crustacean fisheries ranking highest at 7.9 kg. Another study estimated Norwegian fisheries to produce up to 14 kg of CO2 equivalent emissions per kg of protein (Madin & Macreadie 2015)[37], although this study included transport of seafood products in that calculation. A Swedish study of imported American Lobster (Borthwick 2019[38]) reported a footprint of 5.5 kg emissions per kg of edible product at landing, with 1.59 of those kg coming from fishing bait and fuel.

Sources that compare proteins have often shown lobster and shrimp (again, in broad and combined categories) to have higher greenhouse gas emissions than other proteins, including chicken, pork, and in some cases beef (Parker et al 2018[36], Bryce 2018[39]). Sources estimate emissions from the entire supply chain of 1) beef to be about 60 kg CO2 equivalent emissions per kg protein, 2) lamb to be 24 kg CO2 equivalent emissions per kg protein, 3) farmed prawns to be about 12 kg CO2 equivalent emissions per kg protein, and 4) pork to be 7 kg CO2 equivalent emissions per kg protein[40].

The 2.89 kg of emissions (resulting from the capture and processing of one kg of Luke's lobster) places it strongly on the low end of the 0.2 to 7.9 kg of CO2 equivalent emissions per kg range discussed above, with Massachusetts crab even lower at 2.11 kg. It is in line with the Borthwick 2019 study indicating that fishing activities contributed to 1.59 kg of emissions per kg of edible American Lobster product. Borthwick's overall emissions estimate (5.5 kg per kg product) included emissions incurred from post-fishing transport of lobster to Sweden; this transport results in a higher total emissions estimate than Luke's lobster, as the lobster considered here is not shipped beyond the United States. For comparison, a 1.5 lb steamed Luke's lobster creates 4.48 lbs of emissions if consumed at a restaurant, 3.82 lbs transported to a wholesale distribution center, and 6.89 lbs if shipped direct to the consumer. As expected, these values are lower than lobster shipped to Sweden. The 2.89 pounds of emissions per pound of lobster is a blended average of all the iterations and destinations of lobster products in the Luke's Lobster supply chain, noting that some products and shipment methods register below that number, and others above.

A full discussion of Luke's final products, including transport and additional ingredients, follows below.

COMPARISON OF EMISSION OF LUKE'S PRODUCTS

In table 25, the sum of all emissions for individual Luke's products, including the following, are presented:

- Fugitive, stationary, electricity, and waste emissions from processing of lobster and crab
- Emissions from fishing lobster and crab
- Emissions from catching and transporting bait to catch lobster and crab
- Transportation of lobster and crab from wharves to SeaCo
- Electricity used at wharves
- Emissions from the production of non-lobster and -crab product ingredients

Emissions for restaurant and shack products also include emissions from fugitive, stationary, and electricity from shacks and restaurants, and transportation emissions of products to shacks and restaurants. Emissions for direct to consumer products incorporate transportation of each product to the consumer. Emissions for wholesale products include emissions from the transport of the product from Luke's to a hub where the product becomes the possession of the retailer. (Note that this does not include emissions from transport of each item from the hub to each individual retail location). Transportation emissions used for each category of end-destination—Restaurant, Wholesale, or Direct to Consumer—are calculated by dividing the total emissions from downstream transportation to each destination by the total weight of packages shipped to that destination, and applied to the weight of each product below.

In nearly all cases, the highest amount of downstream transportation emissions are incurred through transportation of Direct to Consumer products. This is because transporting products direct to consumer includes air and ground transportation, and products are transported throughout the United States, including over great distances (e.g., to Hawaii). Freight to wholesale

locations, on the other hand, is limited to ground transportation along specific routes in the continental United States, and we did not have sufficient data to show emissions from wholesale hubs to final retail locations and customers' homes. The same is true for transport to restaurants.

Some products include high emissions ingredients. Dairy and meat products[41] are recognized to have disproportionately high emissions[42] compared to other food products, therefore Luke's items containing dairy and meat products (e.g. Lobster BLT, Lobster Mac & Cheese) have higher emissions than others. Products including mayonnaise also have a higher carbon footprint than others, given the high carbon footprint of mayonnaise stemming from high-emissions ingredients like oils and eggs, an energy-intensive production process, and glass packaging. This contributes to the emissions associated with items such as lobster cakes, which include mayonnaise[43].

Table 25: Emissions from each of Luke's Products, Attributed to Wholesale, Direct to Consumer, and Restaurant Items

Includes emissions from production of ingredients and the fishing, pre-processing, and processing emissions associated with the amount of lobster and crab in each product**. For each product, transportation emissions are broken out by the destination of the final product from Luke's to restaurant, wholesale hub, or consumer.

Dish (emissions calculated per package)	Emissions if Restaurant Product (lbs)	Emissions if Wholesale (lbs)	Emissions if Direct to Consumer (lbs)
Lobster BLT	1.82	1.76	2.07
Lobster cakes (sold in 8 oz packages)	1.82	1.61	2.63
Frozen raw lobster tails (8 oz)	*	1.28	2.31
Frozen cooked lobster claw and knuckle (8 oz)	*	1.28	2.30
Lobster Bisque (12 oz)	0.98	0.81	2.35
Lobster Mac & Cheese (16 oz)	6.29	5.85	7.90
Lobster Rolls (2 oz)	0.81	0.68	1.66
Lobster Rolls (4 oz)	1.18	1.00	2.23
Lobster Rolls (6 oz)	1.55	1.31	2.81
Crab Rolls (2 oz)	0.74	0.60	1.58
Crab Rolls (4 oz)	1.03	0.85	2.08
Crab Rolls (6 oz)	1.33	1.19	2.58
Frozen raw lobster tails (10 lb)	*	29.85	*
60/40 mix crab body meat and spin shell meat (8 oz)	*	1.19	*
Cocktail crab claws (1 lb)	2.38	1.95	4.00
Lobster cocktail claws (1 lb)	2.99	2.55	4.60
Lobster mince meat (1 lb)	*	4.27	*
Whole steamed lobster (1.5 lb)	4.48	3.82	6.89
Whole steamed lobster (2 lb)	5.97	5.10	9.19

* Indicates product is not sold in this channel

** Fishing emissions for the amount of lobster in each product include emissions from fishing fuel, bait fishing, and bait transport. Processing emissions include fugitive, stationary combustion, and electricity emissions incurred from operations at SeaCo. Pre-processing emissions include electricity emissions from wharves and transportation of lobster and crab from wharves.

RECOMMENDATIONS AND CONSIDERATIONS

SUMMARY

This report provides a first step in identifying emissions reduction opportunities for Luke's by assessing emissions pertaining to lobster and crab products through evaluation of Scopes 1, 2, and some categories of Scope 3 emissions. Specific recommendations for additional opportunities to make the next assessment more comprehensive are included in a concluding section. The current emissions in each recommendation category are included to add scale and context to the recommendations and make clear the respective "bucket" of carbon emissions available for reduction. Final prioritization of these recommendations will need to be supported by further cost-benefit and business operations analyses by Luke's, as these decisions are multi-faceted and require consideration of factors beyond the scope of this report.

Note: While emissions from lobster and crab harvest represent the greatest opportunities for reduction of emissions within Luke's supply chain, downstream transportation and product ingredients are also important areas to consider within Scope 3. Once progress is being made on the highest priority adaptations, Luke's should explore whether a food industry supply chain consultant could offer further guidance on maximizing effectiveness and efficiency of downstream transport and specific approaches to collaborating with suppliers and wholesalers to effect change.

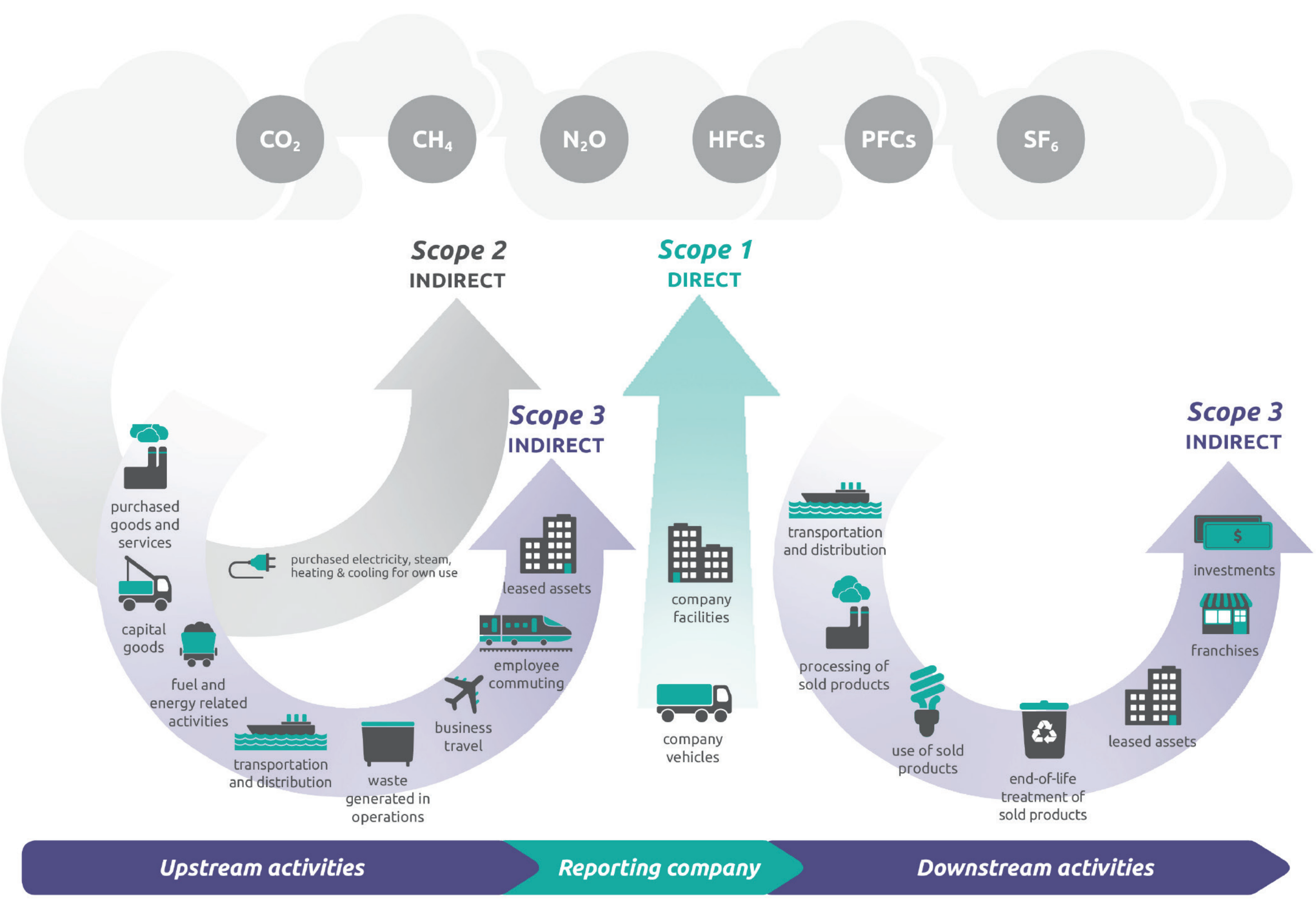
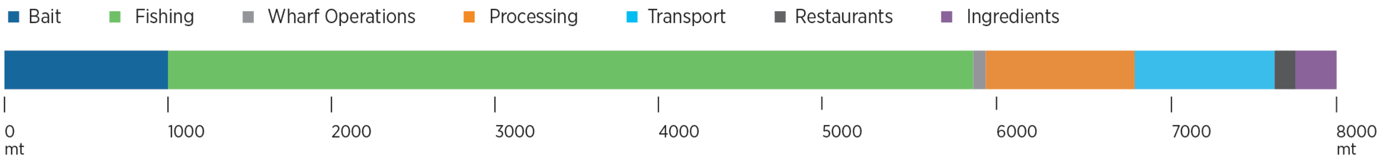


FIGURE 4.
GHG Protocol Scopes and Emissions, image credit WRI/WBCSD

Emissions from the Luke's Lobster Supply Chain for Lobster and Crab Products



BAIT

1,103 CO_2 emissions (mt/yr)

BAIT FISHING 522 CO_2 emissions (mt/yr)

BAIT TRANSPORT 581 CO_2 emissions (mt/yr)

FISHING

4,727 CO_2 emissions (mt/yr)

LOBSTER & CRAB FISHING 4,727 CO_2 emissions (mt/yr)

WHARF OPERATIONS

107 CO_2 emissions (mt/yr)

ELECTRICITY USED 107 CO_2 emissions (mt/yr)

PROCESSING

797 CO_2 emissions (mt/yr)

PROPANE/NATURAL GAS LOBSTER STEAMERS 546 CO_2 emissions (mt/yr)

REFRIGERATION 174 CO_2 emissions (mt/yr)

ELECTRICITY AT PROCESSING PLANT 74 CO_2 emissions (mt/yr)

COLD STORAGE FACILITY 3 CO_2 emissions (mt/yr)

TRANSPORT

566 CO_2 emissions (mt/yr)

LOBSTER AND CRAB DELIVERY FROM WHARVES TO LUKE'S 173 CO_2 emissions (mt/yr)

DIRECT TO CONSUMER TRANSPORT: UPS GROUND AND AIR 132 CO_2 emissions (mt/yr)

WHOLESALE GROUND TRANSPORTATION 244 CO_2 emissions (mt/yr)

LUKE'S-OWNED VEHICLES 17 CO_2 emissions (mt/yr)

RESTAURANTS

269 CO_2 emissions (mt/yr)

GAS AND PROPANE AT SHACKS AND RESTAURANTS 85 CO_2 emissions (mt/yr)

ELECTRICITY AT SHACKS AND RESTAURANT 170 CO_2 emissions (mt/yr)

REFRIGERATION AT SHACKS AND RESTAURANTS 14 CO_2 emissions (mt/yr)

INGREDIENTS

429 CO_2 emissions (mt/yr)

PRODUCT INGREDIENTS 429 CO_2 emissions (mt/yr)

FIGURE 1.
Total assessed emissions by operations category

LOBSTER AND CRAB HARVEST | BAIT AND FUEL USED

As demonstrated in the graphic above, the parts of the supply chain with the highest emissions and greatest opportunities for reduction include bait and fuel used for fishing - items over which Luke's has no direct control. What Luke's does have is a strong relationship with its suppliers, built on mutual understanding and respect. These unique connections can serve as the foundation for improvement, leveraging the recommendations below as a starting point:

Work With the Lobster Industry to Reduce Emissions Related to Bait Used in Lobster Fishing

- **Bait (Current Emissions 1,103 mt - Scope 3, Category 1a and 1b)**
  - Because Luke's is affiliated with a bait company, there is a unique opportunity to influence a significant source of Scope 3 emissions. By considering both the location/transport and the fishing method or source of the bait it sells, the bait company can put more low-emission bait products into the market and the fishing process. To reduce emissions associated with bait fishing, prioritize bait that is a byproduct of another industry, such as pig hide or tuna heads, or is known to have more efficient fishing practices[44]. To reduce emissions associated with bait transport, switch bait purchased and sold to the lowest GHG producing sources, generally domestic, and procure from sources as close to lobster and crab harvesters as possible. (581 mt for bait transport, 522 mt for bait fishing)
  - Engage in outreach with fishermen and articulate the multiple values of using bait that is domestic, locally sourced, and/or a byproduct of another industry (i.e. discarded fish heads/racks or pig hide).
  - A longer-term option is exploration of alternative bait sources from fish processing, which should be done cooperatively with processors of wild harvest and aquaculture companies. For example, byproducts from salmon processing are not currently used for bait because of concerns about salmon disease transmission. A cooperative effort by researchers, regulators, and fishing interests could revisit this and other options, investigating the possibility that improved bait processing techniques could address fish health concerns and open up pathways to more sustainable, low-emissions bait sources.

- **Fuel Used During Fishing (Current Emissions 4,727 mt - Scope 3, Category 1b)**
  - A significant opportunity for emissions reduction relates to fuel use during fishing. This would require Luke's partnership, cooperation, and ongoing investment with fishermen. Options include using renewable or biofuels, switching to all-electric or hybrid-electric motors, or otherwise reducing fuel consumption during fishing. The savings in emissions for each of these options would require significant research into emissions of all potential replacement engines and vessels. It is recommended that Luke's collaborate with existing efforts, like the work being done in Maine by John Hagan and Richard Nelson[45].

WHARF OPERATIONS

Luke's is well positioned to use its established relationships with wharves to work collaboratively on initiatives that will reduce emissions from wharf operations. These recommendations will not only reduce Luke's GHG emissions but also stand to improve the wharves' operational efficiency and reduce costs for suppliers.

- **Purchased Electricity at Wharves (Current Emissions 107 mt - Scope 2: Luke's-operated wharf and Scope 3, Category 1c: all other wharves)**
  - Continue to work with wharves to explore switching wharf operations to renewable energy sources. Solutions such as installation of solar panels and purchase of RECs are options, and viability of each will vary depending on each wharf's unique situation. If it becomes feasible to generate all electricity at wharves by renewable energy sources, that would remove 107 mt of emissions.

PROCESSING

Because Luke's operates its own processing plant (SeaCo) and the company has direct control over some significant sources of Scope 1 and 2 emissions, processing represents a significant source of opportunity for emissions reductions. We offer the following recommendations in this regard:

Explore Lower-Emissions Options for Processing Equipment and Fuels

- **Natural Gas and Propane (Current Emissions 546 mt - Scope 1, Stationary Combustion)**

  Natural gas and propane usage for processing at SeaCo accounts for 546 metric tons of emissions, which is both a significant number and an aspect of the supply chain that Luke's can directly control. Several options may exist for addressing these emissions at SeaCo specifically:
  - Emissions resulting from stationary combustion may be reduced by using renewable natural gas rather than non-renewable fossil fuels and natural gas. Renewable natural gas (RNG) is derived from the capture of methane from natural sources such as animal waste and from already ongoing activities like wastewater treatment and landfills. Explore options for switching to RNG for high-emissions processing and steaming equipment when it becomes an option. Unitil, the company supplying gas to SeaCo, is "actively soliciting RNG program proposals to integrate with our system." While it is unclear how Unitil's program will pan out, it would be worthwhile for Luke's to engage in dialogue with this and other utility providers to demonstrate a demand for RNG supply, credits, and/or other more renewable energy options. Switching to RNG would not necessarily eliminate stationary combustion emissions entirely, as emissions factors may include the full life cycle of fuel production, and would therefore include emissions from the transport and delivery of the fuel. Utilizing RNG credits or partial RNG delivery could be viewed as a transitional strategy as a more impactful long-term solution is developed.
  - Luke's has had early conversations with a wastewater consultant regarding the creation of a biodigestion system to turn processing waste into RNG on site at SeaCo. This is likely to be a high dollar investment with a long development timeline, but it should be pursued if possible because it represents a true and reliable

source of RNG to power equipment that cannot easily be transitioned to electric, like lobster steamers.

- Explore the possibility of switching processing equipment to electric. Switching to low-energy-use electric heating units, particularly given that Luke's is committed to purchasing renewable wind energy, is recommended to reduce emissions associated with stationary combustion from heat. A reputable equipment dealer can offer information about the most current technology available and the cost-benefit analysis on switching major equipment.

Gases and Vapors from Appliances (Current Emissions 174 mt - Scope 1, Fugitive Emissions)

It is recommended that Luke's Lobster explore opportunities for switching to equipment that uses low GWP[46] refrigerants as equipment is due to be replaced, as disposal of high GWP refrigerants still results in fugitive emissions, and the overall emissions reduction (outlined below) is relatively low when compared to the cost to replace appliances.

- 100% of units at SeaCo use refrigerants that the California Air Resources Board (CARB) considers high-GWP refrigerants.

- If each SeaCo unit was replaced with a unit using the refrigerant 449a, which has a lower GWP than most refrigerants at SeaCo, although it is still considered high GWP (assuming new units have the same refrigerant capacity as current units), emissions could be reduced from 174.35 to 77.20 metric tons CO2/operating year.

- If each SeaCo unit was replaced with a unit using the low GWP (GWP=4) refrigerant R290 (assuming new units have the same refrigerant capacity as current units), emissions could be reduced to 0.22 metric tons CO2/year.

- If these units were replaced with a unit using the low GWP (GWP=5) refrigerant R600a (assuming new units have the same refrigerant capacity as current units), emissions could be reduced to 0.28 metric tons CO2/year.

- Remote units (commercial refrigeration units commonly used in restaurants) using R449a are available. Standalone and remote units using R290 and R600a are also on the market. It is recommended that Luke's work with a reputable appliance dealer to identify the best options and timing for replacement.

- R-600a, 449a, and 290 refrigerants are currently used in some on-the-market stand-alone systems and remote condensing units, and are both "U.S. EPA SNAP-approved subject to use conditions for stand-alone refrigerators, freezers, and reach-in coolers" (EPA: Transitioning to Low-GWP Alternatives document[47]). R-600a refrigerators and freezers are available from many manufacturers, including many options from Turbo Air and some units from Black + Decker already in use at Portland Pier. Examples of chillers, refrigerators, and freezers that use R-290 refrigerant include a Preprite blast chiller, a Sigilus chiller available from Intarcon, and Beverage Air and Avantco units already used in Luke's shacks. Some R-449a units are already in use at SeaCo.

This level of emissions reductions would not be realized in one year even if all units were replaced in one year, as emissions from the disposal of current units and the emissions of existing units, which would vary by unit, would need to be accounted for in the analyses. It is recommended, instead, that as equipment needs replacement, it be replaced with refrigerators, freezers, and condensers that use low-GWP refrigerants. The exact amount of emissions increase caused by disposal cannot currently be calculated, as it requires knowing the amount of refrigerant remaining in each piece of equipment at the time of disposal, as well as the amount recovered during disposal. Proper disposal needs to be handled by a disposal company, often the company supplying and installing new equipment.

Reduce the Use Of Non-Renewable Electricity Purchased Electricity (Current Emissions 74 mt - Scope 2, Purchased Electricity)

- The source of electricity purchased is often negotiable with electricity companies. Purchasing energy from renewable sources will reduce emissions. It is noted that Luke's switched to renewable wind energy midway through the reporting year. Emissions reported include those from non-renewable sources (the first part of the year) and renewable wind energy (the second part of the year). Emissions in the next calendar year are projected to be much lower, as wind energy will fully replace non-renewable energy in several Luke's locations for the full calendar year. Projections for anticipated emissions reductions are included in Scope 2 tables, showing that SeaCo has the potential to use RECs to bring emissions from purchased electricity to zero.

- Beyond this, GHG emissions from purchased electricity may be reduced by switching to lower energy use equipment. In a practical sense, replacing appliances solely for the purpose of reducing emissions is not a worthwhile endeavor, as each appliance is only responsible for a small fraction of Luke's emissions each year and replacement units are costly relative to the realized reductions. As with fugitive emissions, it is recommended that replacement with low energy alternatives take place as equipment is due to be replaced. This does, however, represent true emissions reductions versus offsets through RECs, so is worth pursuing as opportunities arise.

TRANSPORT

Downstream, post-processing emissions on Luke's lobster and crab products vary widely depending on the final product and whether it winds up being distributed via a restaurant/shack, direct-to-consumer sale, or wholesale. While the reduction opportunities are not as significant as the lobster/crab harvest aspects of the supply chain, the following recommendations address ways to improve operations and emissions across these channels.

Reduce Emissions from Upstream Transport of Products From Wharves to Luke's

▶ **Upstream Transport (Current Emissions 173 mt - Scope 3, Category 4)**

- Reducing emissions from transport of lobster and crab from wharves to SeaCo can be accomplished if Luke's collaborates with suppliers to maximize efficiency. Reducing the number of trips or total distance traveled would reduce emissions. This can be achieved by transporting lobster and crab from multiple wharves together to SeaCo. This would require close coordination among Luke's and various wharves from which lobster and crab are purchased, but would likely be a low cost method of reducing emissions.

- This category represents 173 metric tons of emissions; while not the most impactful category, improvements here could be low-or-no cost to Luke's and may even represent financial savings. Better coordination as described above could have an immediate impact on emissions while also streamlining operations, all without any expensive infrastructure upgrades. Luke's should also work with wharves to encourage transportation providers to switch to lower-emissions or fully electric trucks.

Reduce Emissions from Downstream Transport of Products

▶ **Downstream Wholesale Distribution (Current Emissions 244 mt - Scope 3, Category 9)**

- Investigate ways of reducing downstream transport emissions through optimization of shipping schedules and exploring lower-carbon shipping options and/or offsets.

- Luke's should encourage existing transportation providers to switch to lower-emissions or fully electric trucks. Alternately, explore switching to shipping companies already using lower-emissions vehicles or imminently planning to make a switch.

▶ **Direct to Consumer Distribution**
(Current Emissions 132 mt - Scope 3, Category 9)

- Luke's now offsets 100% of emissions from UPS shipments, so this reduction is already in place, but is not reflected in this report because the switch did not take place until January 1, 2022. This will represent a reduction of approximately 132 mt. Additional methods of emission reduction from shipping and transport should be routinely explored as part of the operations optimization process to reduce the need for offsets, such as analyzing whether any overnight air shipments could ship equally well with two-day ground shipping.

▶ **Luke's-owned Vehicles**
(Current Emissions 17 mt - Scope 1, Mobile Combustion)

- Emissions from mobile combustion make up the smallest component of Luke's direct emissions (14.81 mt) so reduction of these emissions will have a lower impact than reducing other categories of emissions listed above. When vehicles need replacement, however, replacement with fully electric vehicles would lead to emissions reductions. Prototypes of fully electric, medium duty refrigerated vehicles have been debuted at various events. As these vehicles become available, replacement of Luke's current transport vehicles with them would virtually eliminate Scope 1 mobile combustion forthe company.

RESTAURANTS

Luke's restaurants and shacks represent a relatively small portion of the supply chain emissions, especially since RECs have been used to offset electricity usage at many locations. Still, more progress can be made with additional RECs, switches to renewable energy sources, and utilization of more efficient equipment as replacements are required.

▶ **Restaurants/Shacks**
(Current Emissions 267 mt - Scopes 1 & 2)

- With the exception of recommendations related to refrigerants and fugitive emissions, all of the recommendations outlined for the SeaCo processing facility should be considered for each restaurant and shack location, albeit on a smaller scale. It should be noted that 100% of units at shacks already utilize low GWP refrigerants.

- Transitioning all Luke's food service properties to RECs or direct renewable energy sources, such as solar panels, offers the opportunity to offset an additional 73 mt of emissions.

INGREDIENTS

Product ingredients offer opportunity for a variety of small, individual choices to add up to significant emissions reductions. By considering the inputs of each product and working collaboratively with suppliers, Luke's can improve its own footprint and encourage others to do the same.

▶ **Product Ingredients**
(Current Emissions 429 mt - Scope 3, Category 1d)

- Inform partner manufacturers and ingredient suppliers of Luke's desire to source the lowest-emission ingredients possible and engage with them to encourage emissions reduction. Science Based Targets offers a full report on best practices for managing GHG emission in the supply chain, including specific guidance for engaging with suppliers and setting reduction goals within this complicated scope area48. In instances where collaboration with suppliers is not feasible or effective, pursue new suppliers where feasible and consider the report's suggestions for procurement policy as guidance.

- Now that ingredient emissions have been quantified, consider viable changes to menu items that would reduce the need for especially high-emissions ingredients (like bacon and cheese). However, we acknowledge that such decisions involve implications well beyond consideration of reducing carbon emissions and will likely require financial and customer preference analyses that are outside the scope of this report.

ORGANIZATION-WIDE OPPORTUNITIES

This analysis represents an important first step in Luke's journey to net zero and has revealed additional operational improvements that would serve to further inform and empower the company's emissions reduction efforts.

▶ **Comprehensive Emissions Tracking**

- Some emissions estimates in this analysis have been calculated using proxy values due to the lack of available data. Developing and implementing a comprehensive emissions tracking program and protocols will provide additional data needed to further refine emissions measurement, thereby reducing uncertainty. This would also further enable the completion of Luke's stated desire to conduct a full organizational assessment.

- Examples of this are called out throughout the report and include things like more detailed records of transportation/ mileage/cargo logs. In some cases, improved data collection related to Scope 3 could improve the accuracy of significant numbers like fishing fuel and downstream transportation, but these operations are outside of Luke's direct control. Working closely with suppliers, for example, to identify exact shipping routes taken for each shipment, will be key. Data on transport of lobster and crab from wharves to Luke's is based on distance traveled, with shipment weight calculated as the total weight per year divided by the number of trips per year. Accurate values of the weight in each shipment and actual distance traveled on each trip would allow for more precise calculations of emissions.

▶ **Full Organizational Carbon Emissions Analysis**
Complete a full organizational carbon emissions analysis. This report assesses lobster and crab products and certain scopes and categories of emissions. Estimates of emissions associated with one Luke's menu or grocery item are therefore not comprehensive, as certain emissions categories are not included. Scope 3 categories that were not included in this analysis but should be considered as part of a full organizational analysis include:

- Category 2: Capital goods (emissions from extraction, production, and transportation)
- Category 6: Business travel in vehicles not owned or leased by the company
- Category 7: Employee commuting
- Category 8: Operation of upstream leased assets
- Category 10: Processing, by downstream companies, of products sold by the reporting company
- Category 11: Use of sold products
- Category 12: Waste disposal and treatment of products sold by the operating company
- Category 13: Operation of downstream leased assets
- Category 14: Operation of franchises, including international locations
- Category 15: Operation of investments

The combination of more accurate calculations from more complete data sets and the comprehensive view offered by a full organizational assessment will allow Luke's to analyze where to best concentrate efforts for ongoing reductions by showing the relative value of all GHG emissions-generating activities.

CONCLUSION

Luke's effort to quantify emissions from key lobster and crab products marks a significant move forward and further demonstrates the company's commitment to environmental stewardship. This initial step has begun to establish a collaborative framework from which to pursue important next steps, including execution of a full organizational analysis which will be necessary to holistically understand the full scope of efforts toward carbon neutrality. Furthermore, implementation of the recommendations contained herein will advance emissions reductions within Luke's operations and foster opportunities for improvements within the Maine lobster industry as a whole.

This work will take ongoing and expanding collaborations between Luke's and other partners throughout its supply chain to make reduction progress on identified emissions and to understand new issues regarding GHG emissions and reductions opportunities that emerge in the future. These include ongoing discussions with lobster harvesters and wharves to identify and reduce GHG emissions from lobster boats and fishing operations. Luke's environmental ethic and increasing commitment to sustained and dedicated multi-party engagement to identify opportunities and development of a mutually beneficial strategy to reduce GHG emissions from the lobster industry will continue to establish the foundation upon which long-term company and industry success can be built.

APPENDIX

Table 26: Emissions Summary (All emissions reported in metric tons/reporting year)

Scope	Category or Type of Emissions	Location	Total CO2 Equivalent Emissions (mt/yr)
1: Direct Emissions	Fugitive Emissions	Shacks	<0.01
1: Direct Emissions	Fugitive Emissions	Portland Pier Restaurant	13.79
1: Direct Emissions	Fugitive Emissions	SeaCo	174.35
1: Direct Emissions	Fugitive Emissions	Vehicles	2.04
1: Direct Emissions	Stationary Combustion: Natural Gas	Shacks	29.73
1: Direct Emissions	Stationary Combustion: Natural Gas	Portland Pier Restaurant	55.27
1: Direct Emissions	Stationary Combustion: Natural Gas	SeaCo	434.71
1: Direct Emissions	Stationary Combustion: Propane	SeaCo	111.00
1: Direct Emissions	Mobile Combustion	Mobile Combustion	14.81
2: Indirect Emissions from Purchased Electricity	Emissions from Purchased Electricity at Luke's-operated Wharf (ME)	Wharf Operations	23.08
2: Indirect Emissions from Purchased Electricity	Emissions from Purchased Electricity at Plant (ME)	Emissions from Purchased Electricity at Plant (ME)	73.85
2: Indirect Emissions from Purchased Electricity	Emissions from Purchased Electricity at Portland Pier Restaurant (ME)	Emissions from Purchased Electricity at Portland Pier Restaurant (ME)	19.71
2: Indirect Emissions from Purchased Electricity	Emissions from Purchased Electricity at Shack Locations (US)	Emissions from Purchased Electricity at Shack Locations (US)	150.11
3: Upstream and Downstream Emissions	Category 1a: Purchased goods and services, emissions from bait fishing	Bait	521.55
3: Upstream and Downstream Emissions	Category 1a: Purchased goods and services, emissions from bait transport	Bait	581.31
3: Upstream and Downstream Emissions	Category 1b: Purchased goods and services, emissions from vessels used in lobster and crab fishing	Fishing	4,727.39
3: Upstream and Downstream Emissions	Category 1c: Emissions from electricity used at wharves	Wharf Operations	84.52
3: Upstream and Downstream Emissions	Category 1d: Emissions from purchased ingredients	Ingredients	429.38
3: Upstream and Downstream Emissions	Category 3: Fuel– and Energy–related activities not included in Scope 1 or Scope 2	Processing	2.52
3: Upstream and Downstream Emissions	Category 4: Emissions from upstream transport between wharves and Luke's properties for lobster and crab delivery	Transport	173.27
3: Upstream and Downstream Emissions	Category 5: Waste generated in operations	Processing	0
3: Upstream and Downstream Emissions	Category 9: Emissions from downstream air transport via UPS	Transport	131.86
3: Upstream and Downstream Emissions	Category 9: Emissions from downstream ground transport via UPS	Transport	0.27
3: Upstream and Downstream Emissions	Category 9: Emissions from non-UPS downstream ground transport	Transport	244.41
		TOTAL	**7,998.93**

SCOPE 1

Table 27: Refrigerant DPWs (All emissions reported in metric tons/reporting year)

Refrigerant	GPW	Low or High (GWP>150 is considered high1)	GWP Value Source
R290	4	low	California Air Resources Board[1]
R600A	5	low	California Air Resources Board[1]
R449A	1397	high	California Air Resources Board[1]
HFC134A	1430	high	Greenhouse Gas Protocol[2]
R22	1810	high	California Air Resources Board[1]
R410A	2088	high	Greenhouse Gas Protocol[2]
R407A	2107	high	Greenhouse Gas Protocol[2]
R452A	2141	high	California Air Resources Board[1]
R404A	3922	high	Greenhouse Gas Protocol[2]

1. California Air Resources Board list of High-GWP Refrigerants: https://ww2.arb.ca.gov/resources/documents/high-gwp-refrigerants
2. Greenhouse Gas Protocol's Global Warming Potential Values: https://ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%20 16%22016%29_1.pdf

Table 28: Scope 1: Fugitive Emissions from Operating Refrigeration in Luke's Shacks (All emissions reported in metric tons/reporting year)

Refrigeration Unit	CO2 Emissions for One Unit (mt)	# Units per Shack	Refrigerant	Refrigerant GPW	Low or High (GWP>150 is considered high1)	CO2 emissions for All Units (mt)
Beverage-Air WTR72AHC-FIP	<0.01	4	R-290	4	low	<0.01
Avantco A-49F-HC 54" Solid Door Reach-In Freezer	<0.01	1	R-290	4	low	<0.01
Avantco A-49RHC Refrigerator	<0.01	1	R-290	4	low	<0.01
Total CO2 Emissions from Refrigeration Equipment in Operating Year for ONE Shack						**<0.01**
Total CO2 Emissions from Refrigeration Equipment in Operating Year for 19 Shacks						**0.01**

Table 29: Scope 1: Fugitive Emissions from Operating Refrigeration and at Portland Pie
(All emissions reported in metric tons/reporting year)

Refrigeration Unit	CO2 Emissions for One Unit (mt)	# Units per Shack	Refrigerant	Refrigerant GPW	Low or High	CO2 Emissions for All Units (mt)
Proxy(1) Wunder Bar Beverage	0.06	1	HFC134A	1430	high	0.06
Lancer Beverage	0.03	1	HFC134A	1430	high	0.03
Intertek Cooler	<0.01	1	R290	4	low	<0.01
Proxy(1) Avantco Freezer	<0.01	1	R290	4	low	<0.01
Proxy(1) Avantco Refrigerator	<0.01	2	R290	4	low	<0.01
Proxy(2) Beverage-Air Refrigerator	<0.01	1	R290	4	low	<0.01
Hoshizaki Freezer	<0.01	1	R290	4	low	<0.01
Hoshizaki Refrigerator	<0.01	1	R290	4	low	<0.01
Atosa Refrigerator	<0.01	1	R290	4	low	<0.01
Beverage-Air Refrigerator 2	<0.01	1	R290	4	low	<0.01
Proxy(2) Cold Room Cooler	13.34	1	R404A	3922	high	13.34
Proxy(2) Scotsman Air Cooled Flake Ice Machine	0.37	1	R404A	3922	high	0.37
TurboAir Refrigerator	<0.01	1	R600A	5	low	<0.01
Proxy(2) Insignia Freezer	<0.01	4	R600A	5	low	<0.01
Black and Decker Refrigerator	<0.01	1	R600A	5	low	<0.01
Total CO2 Fugitive Emissions From Refrigeration Equipment in Operating Year for Portland Pier						**13.81**

Proxy(1): Data not available for model number, data from similar unit used
Proxy(2): Could not access model #, used data from Luke's equipment with similar description

Table 30: Scope 1: Fugitive Emissions from Operating Refrigeration and Air Conditioning at SeaCo (All emissions reported in metric tons/reporting year)

Refrigeration Unit Location (building)	CO2 Emissions for One Unit	# of Units	Refrigerant	Refrigerant GPW	Low or High GPW	CO2 Emissions for All Units
15HC	0.09	1	R22	1810	high	0.09
25HC	0.23	1	R22	1810	high	0.23
26HC	0.23	1	R22	1810	high	0.23
10C	5.03	1	R404A	3922	high	5.03
11C	5.03	1	R404A	3922	high	5.03
4f	8.83	1	R404A	3922	high	8.83
14I	8.12	1	R404A	3922	high	8.12
18I	15.23	1	R404A	3922	high	15.23
1F	22.09	1	R404A	3922	high	22.09
2C	11.04	1	R404A	3922	high	11.04
22C	8.83	1	R404A	3922	high	8.83
12 C	12.18	1	R404A	3922	high	12.18
13C	10.15	1	R404A	3922	high	10.15
20F	22.09	1	R404A	3922	high	22.09
21F	22.09	1	R404A	3922	high	22.09
6C	3.55	1	R407A	2107	high	3.55
9C	8.18	1	R407A	2107	high	8.18
19C	1.64	1	R407A	2107	high	1.64
7C	4.09	1	R407A	2107	high	4.09
8C	4.09	1	R407A	2107	high	4.09
16HC	0.27	1	R410A	2088	high	0.27
23HC	0.14	1	R410A	2088	high	0.14
3F	1.36	1	R449A	1397	high	1.36
Total CO2 Emissions from Refrigeration and Air Conditioning Equipment in Operating Year for SeaCo						**174.58**

Table 31: Scope 1: Fugitive Emissions from Operating Refrigeration Units in Vehicles (All emissions reported in metric tons/reporting year)

Refrigerated Vehicle	CO2 Emissions for One Unit	# of Units	Refrigerant	Refrigerant GPW	Low or High GPW	CO2 Emissions for All Units
Sprinter	0.19	1	R452A	2142	high	0.19
Hino	1.85	1	R452A	2141	high	1.85
Total CO2 Emissions from Refrigeration in Operating Year for Vehicles						**2.04**

SCOPE 2

Table 32: Actual and Projected Scope 2: Energy Reduction by Switch to Wind Energy (All emissions reported in metric tons/reporting year)

Location	Total Estimated Annual CO2 Equivalent Emissions if RECs Had Not Been Implemented	Total CO2 Net Equivalent Emissions After Considering RECs	Total CO2 Equivalent Emissions Avoided by Implementing RECs	Anticipated Additional CO2 Equivalent Emissions to be Avoided be Maintaining RECs Year-Round
SeaCo	297.48	73.85	223.73	73.85
Portland Pier Restaurant (ME)	71.37	19.71	51.66	19.71
Back Bay (MA)	18.67	5.66	13.01	5.66
Bethesda (MD)	11.84	6.16	5.68	6.16
Brickell City Centre (FL)	13.31	13.31	0	0
Brooklyn Bridge Park (NY)	3.93	3.93	0	0
City Hall (IL)	27.60	27.60	0	0
Downtown Crossing (MA)	9.22	2.02	7.20	2.02
Farragut (DC)	12.70	4.76	7.94	4.76
FIDI (NY)	15.67	5.41	10.26	5.41
Garment District (NY)	8.16	8.16	0	0
Las Vegas (NV)	11.45	11.45	0	0
Midtown East (NY)	23.59	23.59	0	0
Penn Quarter (DC)	12.41	4.57	7.84	4.57
Rittenhouse (PA)	17.4	6.68	10.72	6.68
SoMa (CA)	11.3	0	11.30	0
Times Square (NY)	1.41	1.41	0	0
Union Square (NY)	7.23	7.23	0	0
Upper East Side (NY)	22.77	8.20	14.57	8.20
Upper West Side (NY)	15.75	6.32	9.43	6.32
1123 Broadway	0.30	0.30	0	0
27 E. 13th Location	11.98	3.34	8.63	6.32
Luke's-operated Wharf	23.08	23.08	0	0
TOTALS	**648.73**	**266.75**	**381.98**	**169.76**

ENDNOTES

1 Additional details can be found in the Appendix - Table 25.

2 Neufeld D. The Carbon Footprint of the Food Supply Chain. Visual Capitalist. 2020. https://www.visualcapitalist.com/visualising-the-greenhouse-gas-impact-of-each-food/

3 Parker, R.W.R., Blanchard, J.L., Gardner, C. et al. Fuel use and greenhouse gas emissions of world fisheries. Nature Climate Change 8, 333–337 (2018). https://www.nature.com/ articles s41558-018-0117

4 https://unitil.com/blog/what-renewable-natural-gas#:~:text=Renewable%20natural%20gas%20(RNG)%2C,and%20acts%20like%20natural%20gas.

5 https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

6 https://blog.intekfreight-logistics.com/air-freight-vs-ocean-freight-carbon-footprint-environmental-impact

7 Luke's prototype restaurant is a small (less than 2,000 square feet), counter service, limited menu lobster shack, which Luke's calls and this document will refer to as 'shacks.' Luke's operates one larger, full service, expanded menu restaurant in Portland, Maine, which Luke's calls and this document will refer to as a 'restaurant' or 'Portland Pier.'

8 https://lukeslobster.com/blogs/news/earth-day-at-lukes

9 World Resources Institute and World Business Council for Sustainable Development. The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard, revised edition. https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

10 https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

11 Fugitive emissions are the unintentional and undesirable emission, leakage, or discharge of gases or vapors from pressure-containing equipment or facilities.

12 https://www.epa.gov/sites/default/files/2020-12/documents/fugitiveemissions.pdf

13 See Appendix, Table 27 for details and source data.

14 Units and GWP of each are available in Tables 28-30 in the Appendix.

15 https://ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

16 https://ww2.arb.ca.gov/resources/documents/high-gwp-refrigerants

17 Non-fossil fuels can include fuels from geothermal, biomass, and ethanol sources.

18 https://www.epa.gov/sites/default/files/2020-12/documents/stationaryemissions.pdf

19 https://ghgprotocol.org/sites/default/files/Stationary_Combustion_Guidance_final_1.pdf

20 https://www.epa.gov/sites/default/files/2020-12/documents/mobileemissions.pdf

21 A list of REC values by site can be found in the Appendix, Table 32.

22 https://www.epa.gov/sites/default/files/2020-12/documents/electricityemissions.pdf

23 https://www.epa.gov/egrid/power-profiler#/

24 https://www.epa.gov/egrid/download-data

25 https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-nova-scotia.html

26 https://carboncloud.com/

27 https://foodfootprint.nl/en/

28 Goucher, L., Bruce, R., Cameron, D.D. et al. (2 more authors) (2017) The environmental impact of fertilizer embodied in a wheat-to-bread supply chain. Nature Plants, 3. 17012. https://doi.org/10.1038/nplants.2017.12

29 https://myemissions.green/

30 https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

31 https://ghgprotocol.org/calculation-tools#cross_sector_tools_id

32 Sources include a January 30, 2022 article in the Southwest Ledger Newspaper: https://www.southwestledger.news/news/medicine-park-bridge-can-carry-its-weight

33 https://www.boeing.com/resources/boeingdotcom/company/about_bca/startup/pdf/freighters/757f.pdf

34 https://www.aircargo.ups.com/en-US/aircraft

35 It should be noted that Luke's figures of 2.89 lbs of emission per lb of lobster and 2.11 lbs emissions per lb of Massachusetts crab is reflective of RECs purchased to offset electricity use in all possible Luke's-controlled restaurant and processing facilities for a portion of the reporting year. These RECs equated to 381.98 metric tons of emissions, or 0.15 lb per lb of lobster/crab.

36 Parker, R.W.R., Blanchard, J.L., Gardner, C. et al. Fuel use and greenhouse gas emissions of world fisheries. Nature Climate Change 8, 333–337 (2018). https://www.nature.com/ articles/s41558-018-0117

37 Madin E.M.P., Macreadie P.I. Incorporating carbon footprints into seafood sustainability certification and eco-labels. Marine Policy 57, 178-181 (2015).

38 https://studentportal.gu.se/digitalAssets/1748/1748028_louisa-borthwick.pdf

39 https://www.anthropocenemagazine.org/2018/04/carbon-emissions-of-lobster-and-shrimp-outstrip-chicken-and-pork-and-sometimes-even-beef/

40 https://www.visualcapitalist.com/visualising-the-greenhouse-gas-impact-of-each-food/

41 https://www.science.org/doi/10.1126/science.aaq0216

42 https://interactive.carbonbrief.org/what-is-the-climate-impact-of-eating-meat-and-dairy/

43 https://researchportal.bath.ac.uk/en/publications/carbon-foot-print-analysis-and-life-cycle-assessment-of-mayonnais

44 The bait fishing table in the Scope 3 Category 1a section shows differences in emissions from fishing. Pogeys from the Gulf of Maine or New Jersey have low emissions from fishing and relatively low transport emissions, as compared to skate from Iceland which is high on both accounts.

45 https://maineclimatetable.org/electrifying-the-lobster-fleet/

46 https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

47 https://www.epa.gov/sites/default/files/2016-12/documents/international_transitioning_to_low-gwp_alternatives_in_commercial_refrigeration.pdf

48 https://sciencebasedtargets.org/resources/files/SBT_Value_Chain_Report-1.pdf

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